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GEOLOGY OF THE PITTSBURGH AREA

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General Geology Report G 59

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General Geology Report G 59

Geology of the Pittsburgh Area

by Walter R. Wagner
Louis Heyman
Richard E. Gray
David J. Belz
Richard Lund
Addison S. Cate
Curtis D. Edgerton

Prepared in cooperation with the
Pittsburgh Geological Society

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IN MEMORIAM*

CHARLES R. FETTKE

March 25, 1888—May 26, 1959

by

Fenton H. Finn

Consulting Geologist and Engineer

This volume is dedicated to Charles R. Fettke, professor of geology for 43 years at Carnegie Institute of Technology, charter member of the Pittsburgh Geological Society, and a cooperating geologist of the Pennsylvania Geological Survey for 45 years.

Charles R. Fettke graduated from the University of Washington in mining engineering in 1910 and received his Master's degree (1911) and Doctoral degree (1914) in geology and physical chemistry from Columbia University. From 1914 until his death, he was closely associated with the economic geology of western Pennsylvania, especially in the field of clays, glass sands, and petroleum geology.

His study of the glass industry culminated with the publication in 1918 of Report XII of the Third Pennsylvania Geological Survey, entitled, *Glass manufacture and the glass sand industry of Pennsylvania.* This publication has been considered the handbook of this important industry; the study embraces the entire glass industry, from the quarry to the finished product. It includes an exhaustive study of all the important occurrences of sand suitable for glass manufacture in the State. His discussion of the geological conditions necessary in the formation of sandstone used in glass manufacture is truly classical.

Charles Fettke made the first exhaustive study of water-flooding operations in the Bradford Oil Field of northern Pennsylvania which resulted in the monumental and classic publication, *The Bradford Oil Field, Pennsylvania and New York,* 1938, by the Fourth Pennsylvania Geological Survey. It is still a valuable reference for the petroleum industry worldwide as a basic reference for any new project concerned with secondary recovery of oil.

He was the pioneer in subsurface stratigraphy of the Appalachian Plateau in the 1930's and 40's because he was the first in this region to make detailed microscopic studies of well cuttings in which he taught the Appalachian industry the tremendous value of these studies in determining reservoir conditions. He demonstrated the need for this basic knowledge of sedimentary rocks to the understanding of stratigraphic trapping both in exploration for new pools of oil and gas, and to the proper development of newly discovered reservoirs. Through his sincerity and brilliant intellect, Charles Fettke brought to the Appalachian petroleum industry a respect for the science of geology that had not existed prior to his entry into the field.

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* Condensed from Proceedings Vol., Geol. Soc. of America, October, 1960.

Charles R. Fettke's bibliography of more than 130 papers indicates his dedication to geology. He was one of the great members of the geological profession, and his role in the Appalachian area is forever established.

CONTENTS

Page

In Memoriam: CHARLES R. FETTKE by Fenton H. Finn ... v

I. Preliminary considerations by W. R. Wagner and Louis Heyman ... 1

II. Regional geologic setting of western Pennsylvania by Addison S. Cate and Louis Heyman ... 3
- Physiography of western Pennsylvania ... 3
- The age of the rocks of western Pennsylvania ... 5
- Structure of the region ... 7

III. Characteristics and depositional environments of the rocks of Allegheny County by W. R. Wagner ... 8
- Introduction ... 8
- Sandstone ... 9
- Shale and Claystone ... 11
- Siltstone ... 13
- Conglomerate ... 13
- Limestone and Dolomite ... 14
- Coal ... 18
- Variety of rocks ... 19
- Environments of deposition ... 19
  - Open-water environment ... 21
  - Swamp environment ... 24
  - Lake environment ... 24
  - Stream environment ... 26
  - Delta environment ... 38

IV. Stratigraphy by W. R. Wagner ... 41
- Introduction ... 41
- Surface rocks of Allegheny County ... 42
- Naming of surface rocks ... 45
- Distribution of Formations and Groups ... 47
- Depositional environments of Groups and Formations
  - Allegheny Group ... 48
  - Conemaugh Group ... 49
  - Monongahela Group ... 57
  - Dunkard Group ... 57
- Cyclothems, facies, and hiatuses ... 59

Page

V. Structural geology by W. R. Wagner 60
Joints 60
Faults 63
Folds 66

VI. Fossils
Invertebrate and plant fossils by W. R. Wagner 71
Fossil vertebrates from the Pittsburgh area by Richard Lund 80

VII. History of Pittsburgh's Rivers by Louis Heyman 84

VIII. Soils and landslides
Allegheny County soils by David J. Belz 93
Residual soils 95
Colluvial soils 99
Alluvial soils 99
Artificial land types 103
Landslides by Richard E. Gray 103

IX. Economic geology
Introduction by Louis Heyman 105
Coal by Louis Heyman 108
Mine subsidence by Richard E. Gray 111
Petroleum and natural gas by W. R. Wagner 116
Surface and ground water by Louis Heyman 119
Sand and gravel by Louis Heyman 122
Sandstone and limestone by Louis Heyman 123
Clay and shale by Louis Heyman and Curtis D. Edgerton 126

X. Appendices by W. R. Wagner and Louis Heyman ....
1. Table of localities 128
2. Glossary 137
3. Pertinent literature 140

ILLUSTRATIONS

FIGURES *Page*

1. 7½ minute U. S. Geological Survey quadrangles covering Allegheny County 2
2. Geologic setting of western Pennsylvania 4
3. Horizontal layering in sedimentary rocks 8
4. Faster weathering of shale creates an overhanging ledge of sandstone 10
5. Sandstone wedge formed by thickening of individual layers from left to right 11
6. Honeycomb weathering in a lower Glenshaw sandstone . . 12
7. Basal conglomerate in a massive sandstone unit 14
8. Outcrop of Morgantown sandstone along Kennywood Boulevard 15
9. Interbedded limestone and dolomite (Benwood carbonate layer) overlain by shale, siltstone, and sandstone 16
10. Ames limestone at Brilliant Cut 17
11. "Pure" and transitional rock types of Allegheny County . . 20
12. Probable geography of Pennsylvania when rocks of Allegheny County were deposited 22
13. Detailed layering of the Pittsburgh coal seam, Bentley Drive, Pittsburgh 25
14. Abandoned clay pit at Creighton 27
15. Section through the Pittsburgh Triangle showing the erosional valleys of the Allegheny and Monongahela Rivers 29
16. Section across Allegheny valley at lower end of Herrs Island, Pittsburgh 30
17. Cliff Mine Road ¼ mile north of Parkway West 32
18. Basal conglomerate from unit 4 (channel sandstone) of Figure 17 34
19. Cross-bedding (at hammer head) at angles to regular layering 34
20. Laminated floodplain silty shales in lower Pittsburgh Formation 35
21. Modern sun cracks in dried mud 39
22. Fossil sun cracks in a carbonate mud rock from the middle Casselman Formation 39
23. Eras of geologic time and periods of the Paleozoic Era . . 42
24. Subsurface rocks below Pittsburgh 43
25. Generalized columnar section of the exposed rocks in Allegheny County 46

Page

26. Rocks representing lake and swamp environments of the Allegheny Group 49
27. Lake environment of Figure 26 replaced by sandstone and shale of stream environment 50
28. Fossiliferous Pine Creek limestone with underlying open-water shale and siltstone 51
29. A middle Glenshaw channel sandstone showing cut-and-fill relation with underlying shale 52
30. A lower Glenshaw channel sandstone cuts out underlying shale 53
31. Brilliant Cut (Locality 38) 54
32. Thin, fresh-water carbonate rock in upper Casselman Formation 56
33. Lower part of Pittsburgh Formation 58
34. Rockfalls in basal Benwood carbonate layer caused by weathering of underlying shale 58
35. A lower Glenshaw sandstone showing vertical jointing . . 61
36. Pittsburgh coal showing well-developed jointing 62
37. Faulting in lower Casselman Formation 63
38. Faulting in Casselman Formation along B and O Railroad cut, Bakerstown Station 65
39. Dimensional elements of anticlines and synclines 67
40. Section along Route 51 from Lewis Run to past Elizabeth 68
41. Small, naturally formed anticline 69
42. Small syncline in Pittsburgh coal formed by collapse of roof coal after mining out the main bed 69
43. Geologic map of the Pittsburgh-Huntington Basin 70
44. Brachiopods (lamp-shells) 72
45. Brachiopods, Bryozoa, and Coelenterates (corals) 73
46. Gastropods (snails) 74
47. Pelecypods (clams) 75
48. Cephalopods, Crinoids, and fossil bush 76
49. Fossil trees showing characteristics of trunks, roots, and leaves 77
50. Fossil trees showing characteristics of trunks, roots, and leaves 78
51. Fern and fern-like leaves 79
52. Fossil vertebrate remains 82
53. Drainage systems of western Pennsylvania 84
54a. Pre-glacial drainage 86
54b. Present drainage 87
55. Old channels and high level terraces on the lower ends of Monongahela, Youghiogheny, and Allegheny Valleys 89

Page

56. High terrace gravels of ancestral Allegheny River, O'Hara Township 90
57. Section across downtown Pittsburgh showing broad U-shaped rock floor and the relations among the overlying unconsolidated valley-fill deposits 94
58. Soil associations, Allegheny County 97
59. Standard U. S. Department of Agriculture soil texture classes 98
60. Sliding of large blocks along joint planes near Mt. Nebo 104
61. Plan of hypothetical coal mine showing system of room and pillar retreat mining 112
62. Method of supporting a structure 114
63. Grout column 115
64. Oil and gas fields of Allegheny County 118
65. Abandoned sandstone quarry in a middle Glenshaw channel sandstone at Bauerstown 124

PLATES

PLATE (In Pocket)

1. Reference maps of Allegheny County . . . .
   A. Cities, towns, and main roads of Allegheny County . .
   B. Geologic map of Allegheny County . . . .
   C. Structural axes of Allegheny County . . . .
   D. Locality map of Allegheny County . . . .
2. Ancient stream erosion and deposition . . . .
   A. Road cut between Webster and Monessen . . . .
   B. Sketch showing stream channel changes with time . .
   C. Stages I to VI show development of units 1 through 8 of Figure B . . . .
   D. Map view of stream channel migration . . . .
   E. Location of Locality 35 . . . .
3. Detailed map of Pittsburgh showing old Monongahela channel and areas underlain by Pittsburgh coal . . . .

TABLES

TABLE Page

1. Rock types and environments at Brilliant Cut 55
2. Principal residual soils of Allegheny County 96
3. Principal colluvial soils of Allegheny County 100
4. Principal alluvial soils of Allegheny County 101
5. Artificial land types 102

I PRELIMINARY CONSIDERATIONS

by

W. R. Wagner and Louis Heyman
Pennsylvania Geological Survey

This book is intended mainly for the interested adult and the secondary school earth science teacher. It will also introduce the geology of Pittsburgh and Allegheny County to the earth scientist who is unfamiliar with the area.

The Pittsburgh Geological Society originally planned to publish a booklet about the geology of Pittsburgh in honor of the late Dr. Charles R. Fettke, a distinguished member of the society. However, because of insufficient time for field work and lack of funds, the project progressed very slowly until it was taken over by the Pennsylvania Geological Survey who enlarged the book to its present form.

The purpose of this book is to present an interpretation of the geology in and around Pittsburgh with emphasis on specific localities that the reader may readily visit. These localities are selected to illustrate the basic principles of geology.

The application of geological principles and its role in the historical and economic development of Pittsburgh is considered in the sections dealing with soils, landslides, mine subsidence, and mineral resources.

Most of the localities discussed in the text are identified by a locality number, the general location of which is shown by a number on the county location map (Plate 1, Figure D). Should the reader wish to visit a locality, detailed locations are given in Appendix 1, Table of Localities. This table lists for each locality the rock layers exposed, the geologic features to be observed, and the pages in the text where the locality is discussed. The county locality map and Appendix 1 can be used jointly to plan a field trip. If trips involving large numbers of persons are contemplated, the authors recommend that automobile and railroad hazards be given due consideration; hazardous localities are noted under "Comments" in Appendix 1.

The most useful maps for locating oneself in the county are the 7½ minute U. S. Geological Survey topographic quadrangle maps (Scale of one inch equals approximately 0.4 miles). Figure 1 shows the maps that cover Allegheny County. An asset of these maps is that one can readily determine elevations and vertical distances.

For a thorough study of Allegheny County geology, the starred reports in Appendix 3 are very useful. Copies may be referred to at the Carnegie Library and the office of the Pennsylvania Geological Survey, 401 Pittsburgh State Office Building, Pittsburgh.

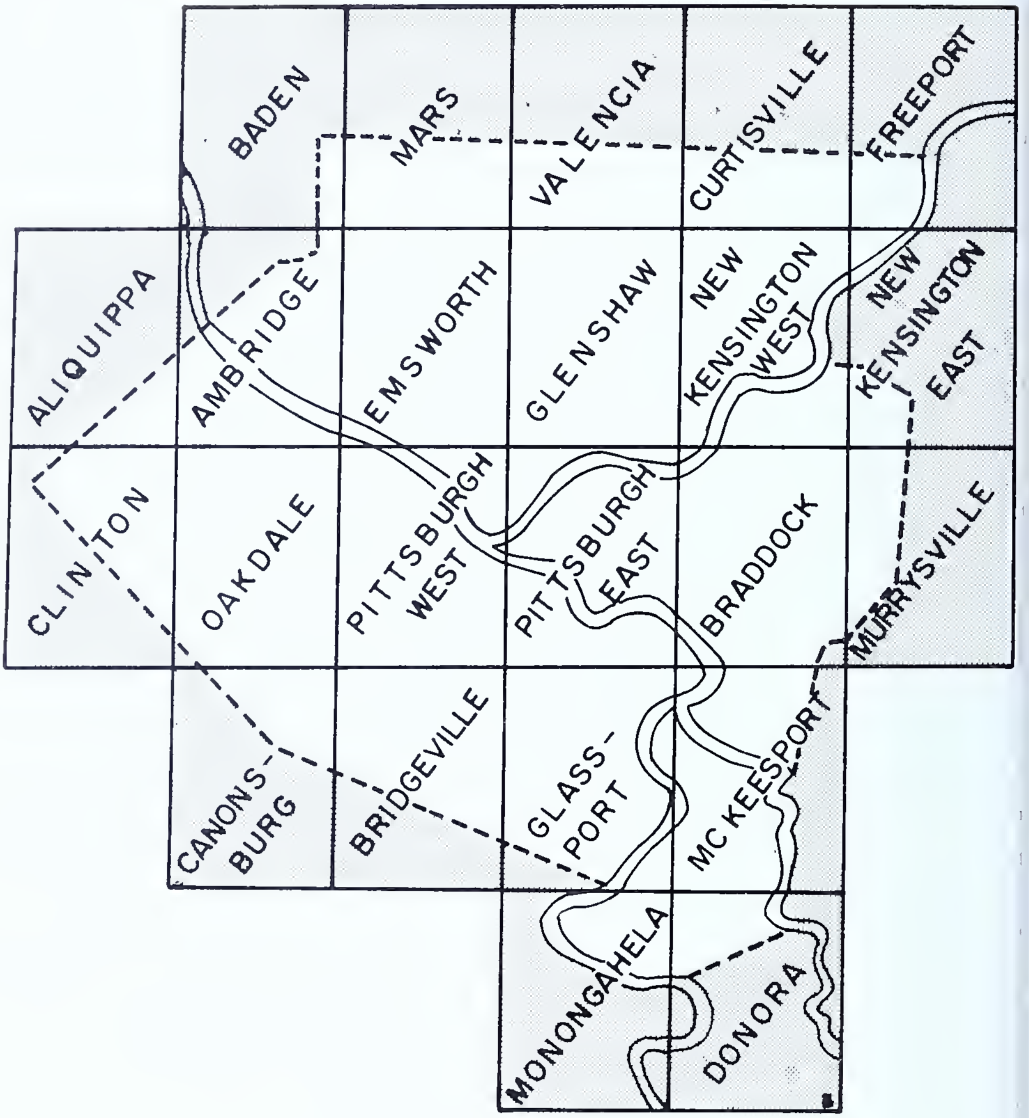


Figure 1. 7½ minute U. S. Geological Survey quadrangles covering Allegheny County.

II REGIONAL GEOLOGIC SETTING OF WESTERN PENNSYLVANIA

by

Addison S. Cate and Louis Heyman

University of Michigan and Pennsylvania Geological Survey

The area to which the reader's interest is invited is Allegheny County, which has at its center the city of Pittsburgh. Plate 1, Figure A (in pocket) is a map of Allegheny County showing towns, rivers, and main roads. Before looking closely at the geology of the county we will place it in the regional setting of western Pennsylvania.

PHYSIOGRAPHY OF WESTERN PENNSYLVANIA

The physiography of a region includes its surface features and the factors which have formed or modified them during the course of time. The divisions based on this definition are called physiographic provinces, and in each physiographic province there is a general geologic uniformity throughout the province.

Western Pennsylvania is located in the "Appalachian Plateaus Province" (Figure 2) where the rocks at the surface are almost flat-lying and give the topography a generally level surface at an altitude great enough to have permitted deep valley cutting by streams. This province extends from central Ohio eastward to the east-facing escarpment known in Pennsylvania as Allegheny Mountain or Allegheny Front. The western part of New York and all of West Virginia except the Eastern Panhandle are also part of the same province.

In Allegheny County the flat hill tops lie at about 1,200 feet elevation with narrow valleys cut 400 to 500 feet below the tops of the hills.

Millions of years ago, a drainage pattern of rivers and their tributary streams was established in western Pennsylvania on a relatively flat, very gently north and west-sloping plain, draining from the south and east toward the area of the present-day Great Lakes. The location of the streams probably was initially controlled by regional fracture systems in the rocks and subtle differences in rock properties.

Once this drainage pattern was established, the topographic relief (difference in elevation between the highest and lowest points of an area) gradually increased as the streams cut down into the plateau. At various times there were gentle uplifts or tiltings of the entire region with the result that the increased slope so created impelled the streams to cut their valleys deeper. In some places, almost canyon-like valleys resulted—

the clifflike face of Mount Washington across the Monongahela from the Triangle section of Pittsburgh and the bluffs on the south side of the Allegheny at Verona-Rosedale and on the north side at Troy Hill-Millvale are examples of such steep slopes. Thus, the present-day relief

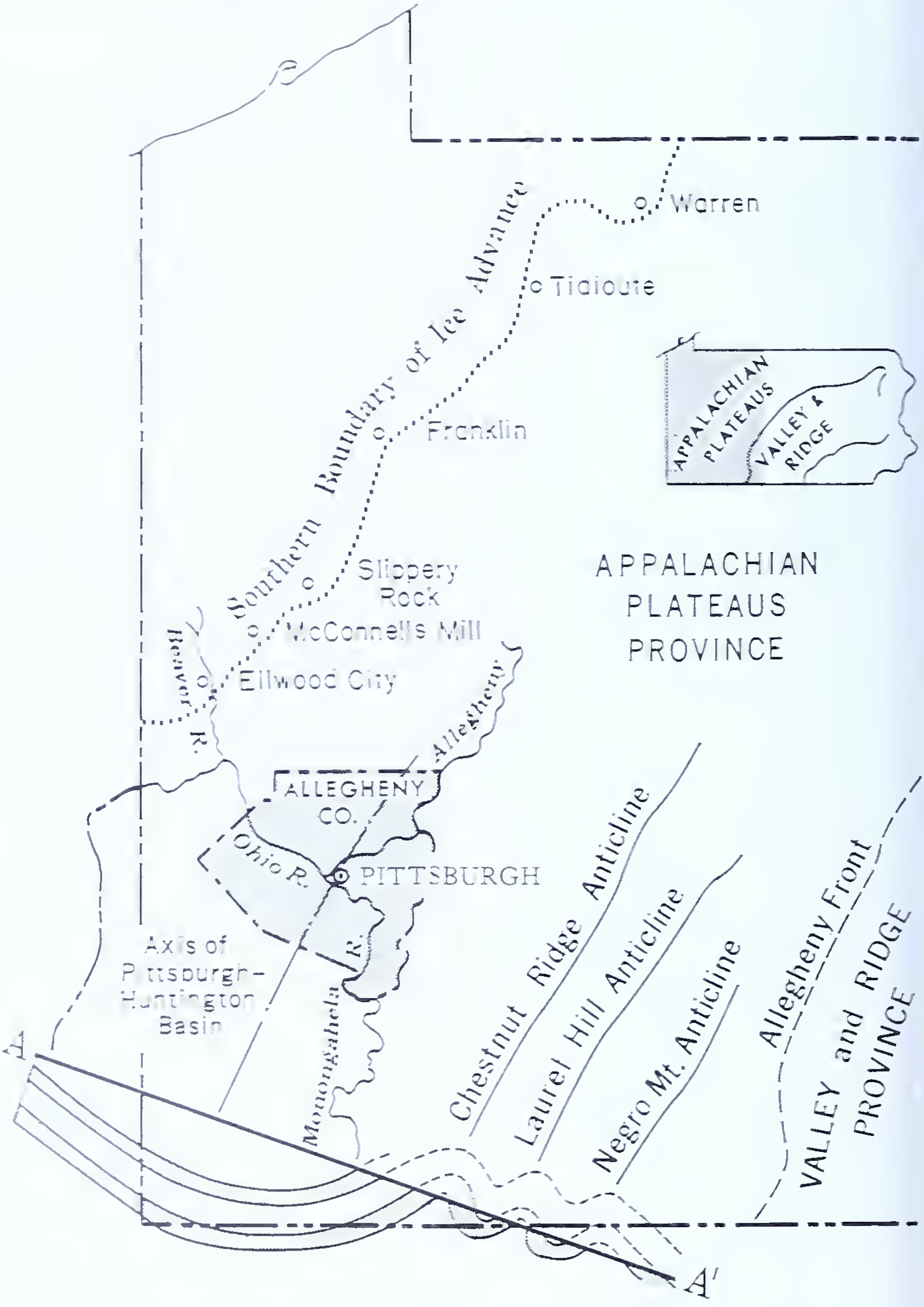


Figure 2. Geologic setting of western Pennsylvania.

we see in western Pennsylvania is largely due to the erosion accomplished by the drainage network.

Another significant influence on the physiography of western Pennsylvania was the glaciers which advanced and retreated across parts of northern Pennsylvania. In the western part of the State, a line drawn from Ellwood City northeast to Slippery Rock, thence to Franklin, and from there northeast past Tidioute through Warren, approximately parallel with the course of the Allegheny River, and north into New York State, marks the southernmost advance of the ice front (see Figure 2). The advance of the glaciers commenced perhaps one-half million years ago and ended as recently as about 11,000 years ago—thus qualifying as the last major geological event that exerted an important influence on the area.

The effect of the glaciers on the rivers of western Pennsylvania was most marked. In preglacial times the rivers flowed north into a drainage basin that was located in the vicinity of present day Lake Erie. As a result of ice damming of their lower courses, the streams were forced to flow in another direction, generally southward. The Ohio River's present course along the southern boundary of Ohio is a partial indication of the extent of the ice in that region; the Beaver River, once a large and important north-flowing stream, was dammed and forced to reverse its flow by the glacial advance. The gorge at McConnell's Mill on Slippery Rock Creek resulted from the erosive power of impounded meltwater pouring out of a glacier-created lake.

The veneer of glacial deposits left behind by the advancing and retreating glaciers and the scraping and leveling of the countryside by the massive ice sheets modified the shapes of the hills and valleys as contrasted with unglaciated topography south of the glacial front.

The effects of glaciation are discussed in more detail in Section VII, the History of Pittsburgh's Rivers.

THE AGE OF THE ROCKS OF WESTERN PENNSYLVANIA

In the earliest geological time, the first portions of the earth's crust were developed; then followed the "primitive ages" of geologic history when the first forms of life appeared, probably in the sea, and sediments began to accumulate as a veneer on the earth's surface. Next there was a time in which animals and plants moved onto the land, and the seas retreated, leaving the continents more and more exposed, and finally the age in which the mammals, including man, developed. On the basis of fossil evidence, the first primitive life stirred on this planet about

3 billion years ago, but it was not until about 800 million years ago that multicellular life evolved.

Time, in a relative sense, is quite important to geologists. With some sort of a geochronometer we can relate geologic events elsewhere in the world to those which occurred in North America. A great variety of fossil organisms and their traces are at present our best way of correlating rock layers from one place to another, by matching either individual "index" fossils or entire fossil assemblages occurring in the strata in question. This tool must be used very carefully however; not *all* rocks belonging to the same geologic unit and having the same character, and in many cases, the same fossils, are necessarily everywhere the same age. Over shorter distances, perhaps as much as several counties, we sometimes find a layer of rock which remains pretty much the same and which we think was deposited almost simultaneously everywhere it occurs.

Layers which may serve as such key "marker beds" are: coals and thin limestones in the midst of thick sequences of shale. Each layer represents a moment in geologic history, but if we compare overlapping areas in which the geologic correlation of layers has been possible with the aid of marker beds and fossils, we can gradually compile most of the geologic history of a region. We can deduce, for instance, that while the sea was spreading over a lowland in one place it was withdrawing from another; this because of the presence of a particular fossiliferous bed in the first mentioned place at the bottom (or start) of a sequence of marine rocks, while at the second place the same fossils, indicative of approximately the same time on the geologic clock, are found at the top (or end) of an otherwise similar sequence of beds.

The basic blocks of time used by geologists and referred to in the reconstruction of earth history are called "periods". A period is usually named for a geographic place—the locality in which the sediments presumably deposited during that period were first described or are best developed. The outcropping rocks of Allegheny County are divided into two sequences, the rocks of the Pennsylvanian Period, named for western Pennsylvania, and overlying them, the rocks of Permian Age, named for the province of Perm in eastern European Russia. Because "period" represents solely an interval of time, another term, "system", is designated to embrace the rocks that were deposited during that interval. Thus, the Pennsylvanian *System* represents all the rocks that were deposited during the Pennsylvanian *Period*.

Below the surface of Pittsburgh, sedimentary rocks older than those of Pennsylvanian age are found in a sequence about 16 thousand feet thick between the base of the Pennsylvanian and the metamorphic rocks forming the "basement" below the sedimentary section (see Figure 24, Subsurface Rocks below Pittsburgh). It is rare, however, that rocks representing all the time elapsed in all the periods are to be found piled successively upon each other in one place—usually there are gaps in the rock record. A gap is due either to non-deposition of sediments during a given time, or to subsequent erosion of the sediments recording a given time span, and is technically known as a hiatus. In western Pennsylvania, parts of all the systems are missing, in some cases a major part. For instance, several thousand feet of Mississippian rocks present in southern West Virginia are absent from the rocks of this area.

The youngest rocks in the region, parts of the Permian System, are exposed in the southwestern part of the State. Devonian rocks, the oldest exposed in southwest Pennsylvania, are exposed where Route 40 crosses Chestnut Ridge east of Uniontown.

The age of the rocks of western Pennsylvania is the concern of stratigraphy and is discussed in Section IV.

STRUCTURE OF THE REGION

The structure, or architecture of the rocks, in this region is fairly simple—the rocks are relatively flat lying, and the stream divides or watersheds are the high points of the land.

The regional structure is a troughlike basin, termed the Pittsburgh-Huntington Basin, the axis of which extends northeast-southwest just about through Pittsburgh (see Figure 2). All rock strata in the basin dip gently toward this axis. The basin contains the youngest rocks in this part of the country, the Permian System, exposed in the axial area, with progressively older rocks exposed towards the basin margin.

Eastward from the Pittsburgh-Huntington Basin, the rocks become more sharply folded. A number of pronounced folds occur, generally aligned with axes trending approximately 30° east of north. Outstanding among these are Chestnut Ridge, Laurel Hill and Negro Mountain Anticlines (Figure 2). Anticlines are folds convex upward; synclines are convex downward. These folds are generally the result of compressional forces which were more intense to the east, in the province called the Valley and Ridge Province.

The eastern edge of the Appalachian Plateau is called the Allegheny Front. This margin is abrupt and distinct in many areas because erosion, gradually wearing back the Plateau rocks from the east, has resulted in a steep erosional escarpment which is located structurally on the west flank of a prominent breached anticline.

The structure of the rocks is more fully discussed in Section V, Structural Geology.

III CHARACTERISTICS AND DEPOSITIONAL ENVIRONMENTS OF THE ROCKS OF ALLEGHENY COUNTY

by

W. R. Wagner

Pennsylvania Geological Survey

INTRODUCTION

The rocks of Allegheny County are sedimentary rocks. Their most obvious characteristic is horizontal layering which is emphasized by the different shades or colors of individual layers and by differences in composition. Figure 3 shows an excavated hillside behind a gasoline station on Banksville Road (Locality 24). Both color and compositional differences accentuate the layering. The dark bands are red and gray claystone whereas the lighter bands are gray carbonate rock and shale.

All sedimentary rocks in the county were originally deposited as layers at the bottom of seas, lakes, streams, or swamps. One group of sedimen-

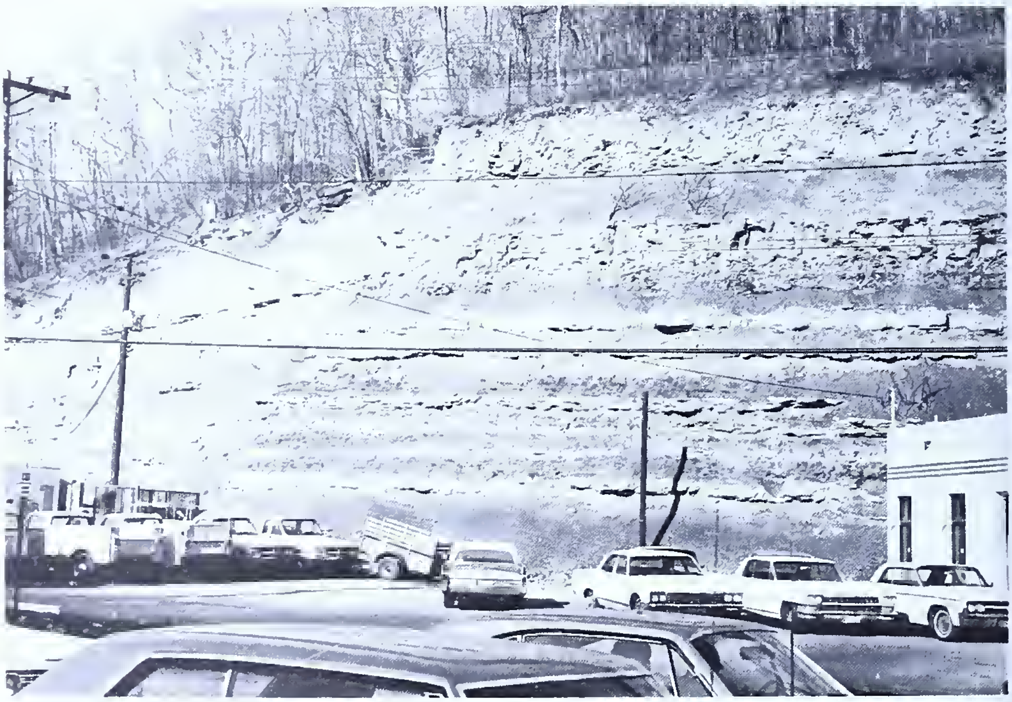


Figure 3. Horizontal layering in sedimentary rocks. Dark layers are red to gray claystones, lighter layers in lower part of cliff are fresh-water carbonate rocks, lighter layers in upper part are shales. (Locality 24—Banksville Road, Route 19, middle Casselman Formation).

tary rocks is composed of particles of sand and mud washed into a body of water. Such rocks are categorized as "clastic" which means composed of fragments transported into their place of deposition. Millions of years after deposition the grains of sand become cemented together into sandstone, and the mud, which is made of particles of clay and silt, is compressed and hardened to claystone, siltstone, or shale. The most common clastic rocks of the Pittsburgh area are sandstone, siltstone, shale and claystone.

A second kind of sedimentary rock is one which begins as a precipitate from lake or sea water and which accumulates on the bottom. Certain limestones and dolomites develop this way and are also common in Allegheny County, particularly in the southern part.

The third variety of sedimentary rock is organic, one containing considerable animal or plant material. Shell limestone and coal are examples from Allegheny County. Shell limestone is made up largely of shell remains, and coal is formed from partially decomposed, altered plant material such as leaves and branches. Coal, of course, is the basis for the industrial development of Pittsburgh but aside from this, both coal and fossil shell limestones are used by geologists as "marker beds" to divide into understandable sequences a column of exposed rock that is more than 1,100 feet thick in Allegheny County.

SANDSTONE

Sandstones are the most conspicuous rocks in the Pittsburgh area; they form the cliffs and steep slopes that occur naturally. A freshly exposed sandstone surface is usually light to medium gray, but a surface exposed for several years to the weathering effects of Pittsburgh climate will turn yellowish, tan, or light brown due to the oxidation of minute amounts of iron compounds dispersed throughout the rock. Weathering also causes the hard white feldspar grains that may be scattered in the rock to decompose into soft, flesh-colored clay. The predominant mineral composing sandstone is quartz and the individual quartz grains are usually bonded together by clay and quartz cement. A sandstone is defined as cemented quartz grains from two millimeters to 1/16 millimeter in diameter. If the cemented grains are more than two millimeters the rock is called a conglomerate and if the grains are less than 1/16 millimeter but more than 1/256 millimeter, the rock is a siltstone. Sandstone, in spite of its weathering, is the most resistant rock of the area and that is why it forms the cliffs, and why it is commonly used as a building stone, particularly in retaining walls.

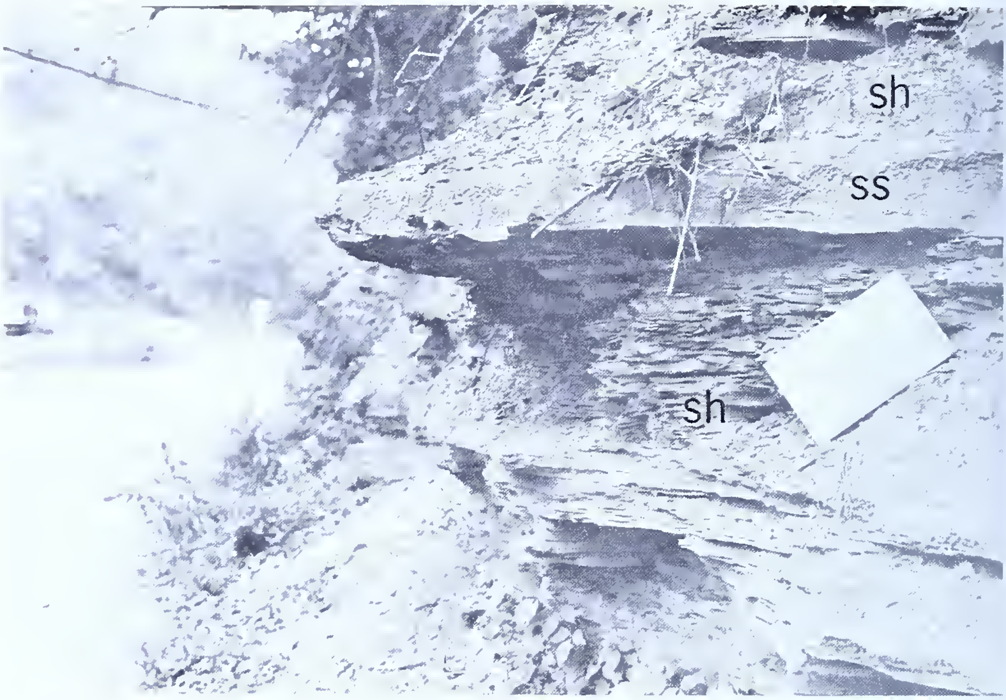


Figure 4. Faster weathering of shale (sh) creates an overhanging ledge of sandstone (ss). Note shale talus pile at base of cliff (lower Glenshaw Formation at Creighton).

The horizontal layering of strata is strikingly emphasized by the results of different weathering rates of sandstone compared to shale and claystone. Along many roads may be seen the almost horizontal boundary between a sandstone above and a shale or claystone below. Shale and claystone weather at faster rates than sandstone and create overhanging ledges of sandstone (Figure 4). As the amount of overhang increases the sandstone eventually becomes unstable and large blocks break off and fall to the road shoulders. These rockfalls are most prevalent during spring wet weather. In the Pittsburgh area, claystone weathers from the face of a cliff at a rate of from 0.2 to 0.6 inches per year (Philbrick, 1959).

Individual layers of sandstone may range from a few inches to as much as 25 or 30 feet in thickness. Many layers are lens shaped, thick in the middle and becoming thinner toward the edges. Figure 5 shows the development of a lens of sandstone made up of several layers in which each layer on the left thickens to the right. At the right the lens has been truncated so that thinning of the right side of the wedge cannot be seen. What generally happens is that as one lens thins and disappears another lens just above or below begins to thicken and replace the lens or layer that terminates. In this parallel yet offset pattern a number of individual lenses may combine to form a sandstone unit which can continue laterally for miles. A sandstone unit may range from less than five feet in thickness to more than 100 feet, the usual thickness, however, being 10 to 50 feet.

Honeycomb weathering may be observed in some sandstones. The process is not well understood but it is generally believed that chemical solution by slightly acid waters combined with mechanical breakdown of the sandstone is concentrated in small pits. Eventually the pits may grow to several yards in diameter. An example of this form of weathering is exposed in a sandstone cliff along the Penn-Central Railroad where Jacks Run enters the Ohio River at the boundary of Pittsburgh and Bellevue (Figure 6, Locality 6).

SHALE AND CLAYSTONE

Shale and claystone are weak and soft rocks, weak in the sense that they weather rapidly and soft in that they can be scratched easily with a knife. Both rocks are composed of clay minerals whose general chemical composition is hydrous aluminum silicate. The clay minerals are so

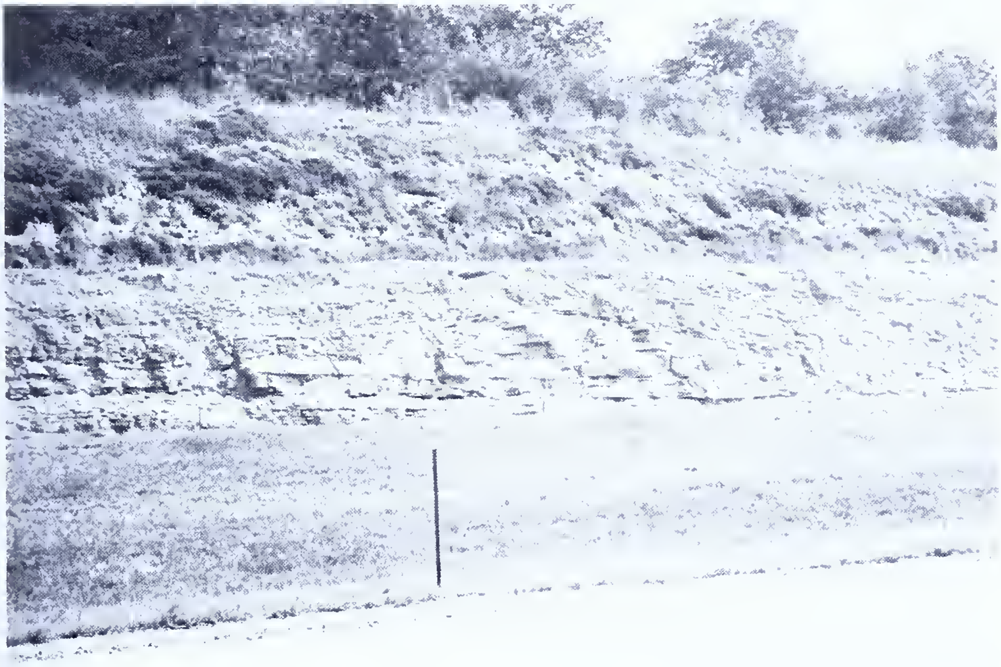


Figure 5. Sandstone wedge formed by thickening of individual layers from left to right (Waynesburg Formation of Dunkard Group along Interstate Route 79 between Bridgeville and Canonsburg).

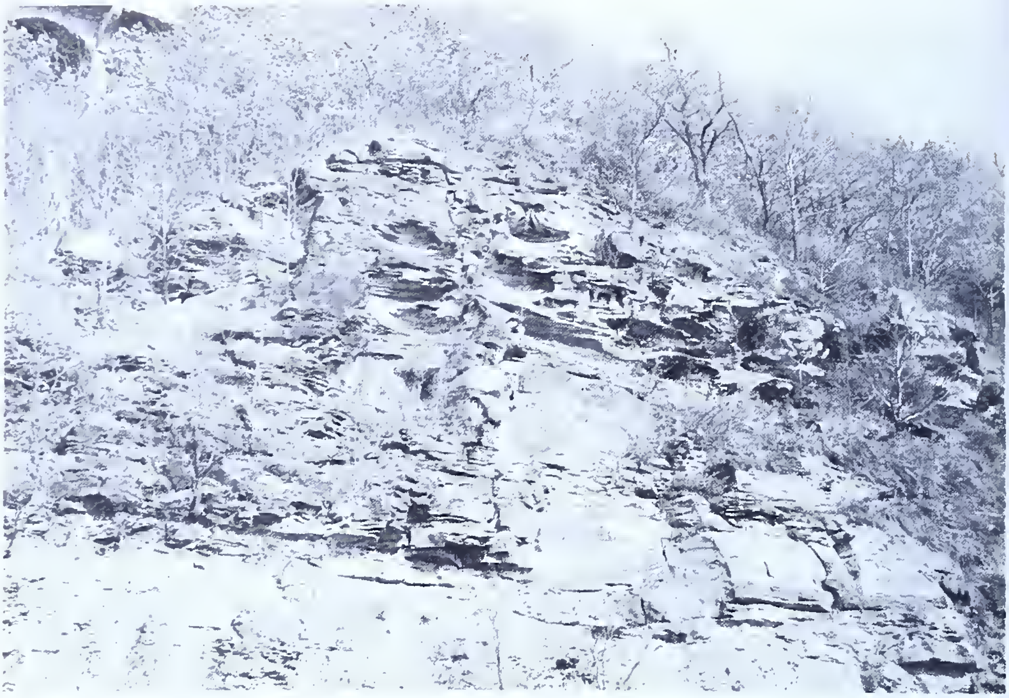


Figure 6. Honeycomb weathering in a lower Glenshaw sandstone. (Locality 6—Penn-Central Railroad at Jacks Run and Ohio River).

fine, less than 1/256 millimeter, that the particles of the rock can be seen only with a powerful microscope. The distinction between shale and claystone is that shale is fissile; it has the property of splitting into thin plates, whereas claystone is without layering, and tends to crumble into irregular fragments upon weathering. Shale can be distinguished from other rocks by its very closely spaced layering. As mentioned before, shale and claystone disintegrate faster than sandstone or limestone and become indented from the face of a slope causing the more resistant rock to stand out in relief. Small pieces of shale and claystone that weather and drop from the hillsides collect at the base of hills as cone-shaped piles of debris called talus. Figure 4 shows a small pile of talus beginning to collect at the base of a cliff.

Claystone and shale display a variety of colors ranging from hues of red and green to shades of gray, dark gray, and black. Dark gray and black shades are caused by organic carbon, the more carbon the darker the rock. In many gray and dark gray shales, particularly those lying above coal seams, black carbonized fossil films representing leaves and wood fragments can be observed. Most clay rocks contain small percentages of iron minerals. When the iron is in a reduced (ferrous) state the rock color is gray or green, but when the iron is oxidized (ferric) the rock becomes red or brown, the change of color being chemically similar to the rusting or oxidation of an iron nail. Units of shale or claystone may show color changes from red to green or gray either vertically or horizontally within the same outcrop. In some cases, notably in claystones, the unit may be mottled or variegated red and green. Color variations from red to gray may be seen in the shale at eye level at the south end of the trolley tunnel at South Hills Junction. Color, especially in clay-rich rocks, is commonly significant in determining the environment in which the rock was deposited.

SILTSTONE

Siltstone is intermediate in grain size between sandstone and the clay rocks. The particle size of siltstone is defined as ranging from 1/16 millimeter down to 1/256 millimeter. All gradations occur from sandstone to siltstone and from siltstone to shale. A sandstone may be silty and a siltstone may contain sand, and silty shales and silty claystones are common rocks. A practical way to differentiate siltstone from sandstone is that the individual grains of sand can be seen by eye, but the grains of a siltstone require the use of a magnifying glass. Grittiness is the determining factor in distinguishing siltstone from shale or claystone. A siltstone rubbed lightly against the teeth or fingernail will feel gritty because of its silt-sized quartz grains whereas a claystone or shale will feel smooth because it lacks grains this large. Siltstones may either be layered or unlayered and possess the same variety of colors as shale and claystone.

CONGLOMERATE

Conglomerate is cemented gravel; it consists of rounded particles larger than two millimeters in diameter or larger than sand size. Gravel is the usual material removed from excavations in downtown Pittsburgh and dredged from the bed of the Allegheny River. The Allegheny deposited the gravels not only in its own bed but also in the downtown triangle. Although gravel usually is found in the Allegheny River valley, conglomerate is rare among the rocks of Pittsburgh. Where it does occur the conglomerate is restricted to the base of the massive sandstone layers and in this position is called "basal conglomerate". A basal conglomerate is exposed on Kennywood Boulevard between Kennywood Park and the Rankin Bridge, one-half mile southeast of the bridge (Figure 7 and 8, Locality 32). The conglomerate consists of dark shale pebbles several inches across in a matrix of fine- to medium-grained sandstone.

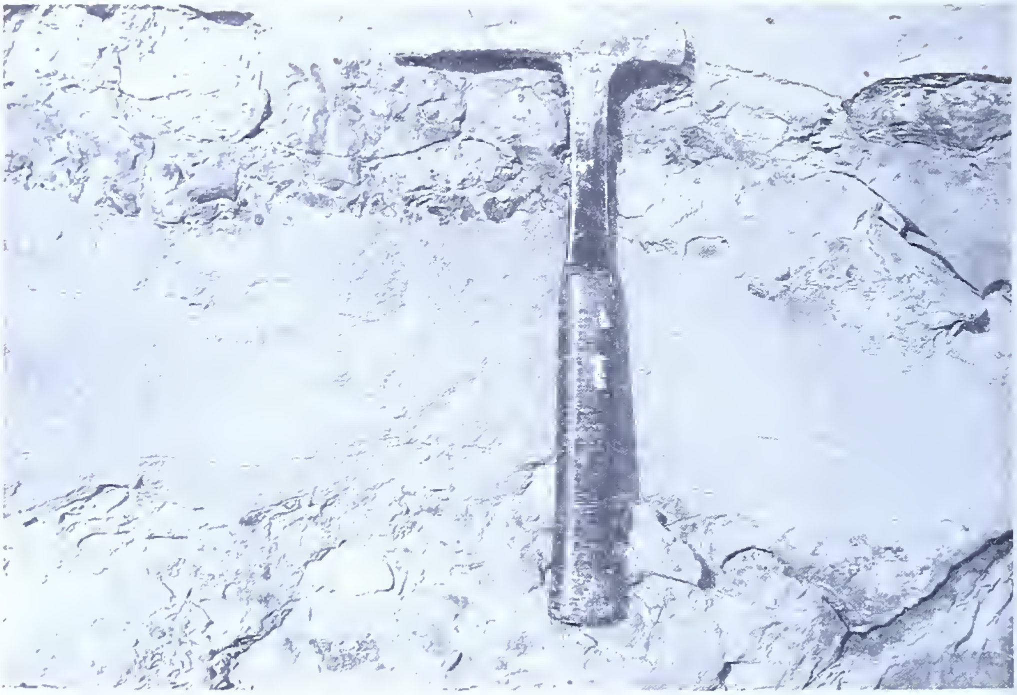


Figure 7. Basal conglomerate in a massive sandstone unit. (Locality 32—Morgantown sandstone along Kennywood Boulevard between Rankin Bridge and Kennywood Park).

LIMESTONE AND DOLOMITE

Limestone and dolomite contain carbonate (CO_3) as part of their chemical composition. Limestone is calcium carbonate ($CaCO_3$) and dolomite is calcium magnesium carbonate ($CaMg(CO_3)_2$). A little experience is necessary to distinguish limestone from dolomite. A drop of dilute hydrochloric (or muriatic) acid on limestone will cause strong effervescence due to the liberation of carbon dioxide (CO_2). Dolomite, however, will effervesce only weakly, if at all. Another difference between the two rocks is that dolomite usually weathers to a yellowish-gray color whereas limestone tends to be gray or blue-gray. The yellowish cast of dolomite is caused by the oxidation of iron (Fe) which substitutes for some of the magnesium (Mg).

At Locality 23 on Route 19 (Washington Road) south of Mt. Lebanon at the junction of Gilkeson Road, the cut in back of Howard Johnson's Restaurant exposes a sequence showing dolomite, limestone, shale and sandstone (Figure 9). The dolomite layers are yellowish-gray and react very slowly to acid compared to the light gray limestone layers. Near the base of the hill the limestone is clayey and, as it weathers, crumbles into irregular fragments. This outcrop also shows that the carbonate rocks jut out from the face of the hill like shelves and the shale is recessed indicating that the carbonates are more resistant to weathering than the shale. Sandstones and carbonate rocks being more weather-resistant than shale, may be confused with one another, and the following differences will aid in making the correct identification. A carbonate rock is soft, that is, it can be scratched with a knife whereas a sandstone cannot be scratched. A carbonate rock, including dolomite if it is powdered, will react to acid and a sandstone will not. Carbonate rocks tend to weather and break with curved surfaces and sandstones have a more blocky appearance. In Figure 9 the undulating surfaces of the carbonate rocks can be contrasted with the more planar surfaces of the sandstone at the top of the photograph.

The carbonate rocks of Allegheny County are divided into "fresh water" and "marine" types based mainly on the fossil content. The fresh-water carbonate rocks contain fresh-water ostracodes (bivalves), small gastropods (snails), and the teeth, scales, and bones of fish, but these fossils are rare. Fresh-water carbonate rocks are the thicker and

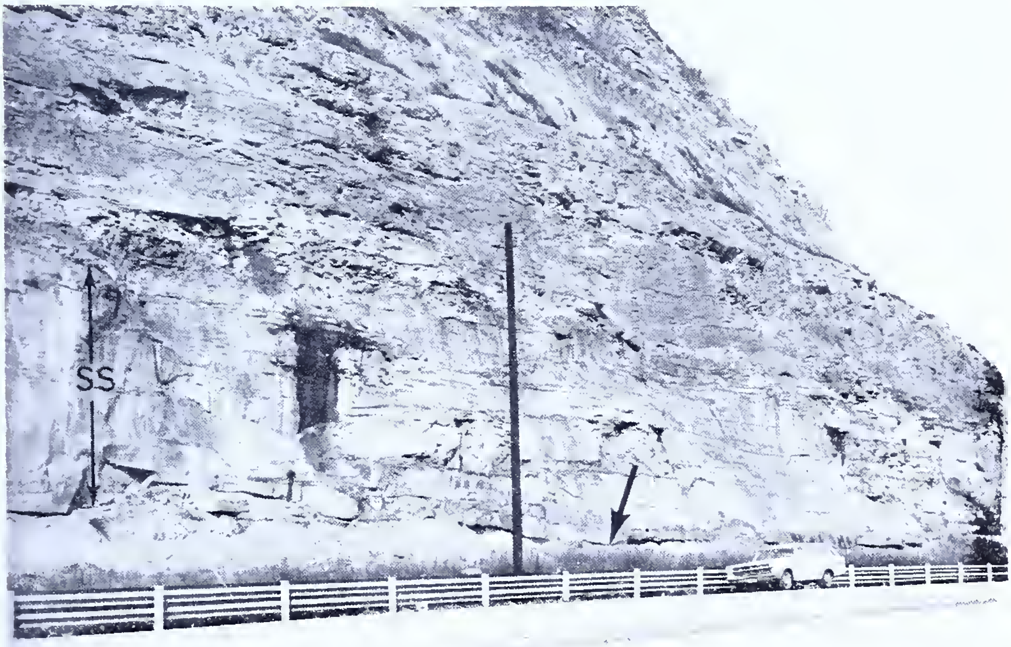


Figure 8. Outcrop of Morgantown sandstone (ss) along Kennywood Boulevard. Arrow shows position of basal conglomerate of Figure 7 (Locality 32).

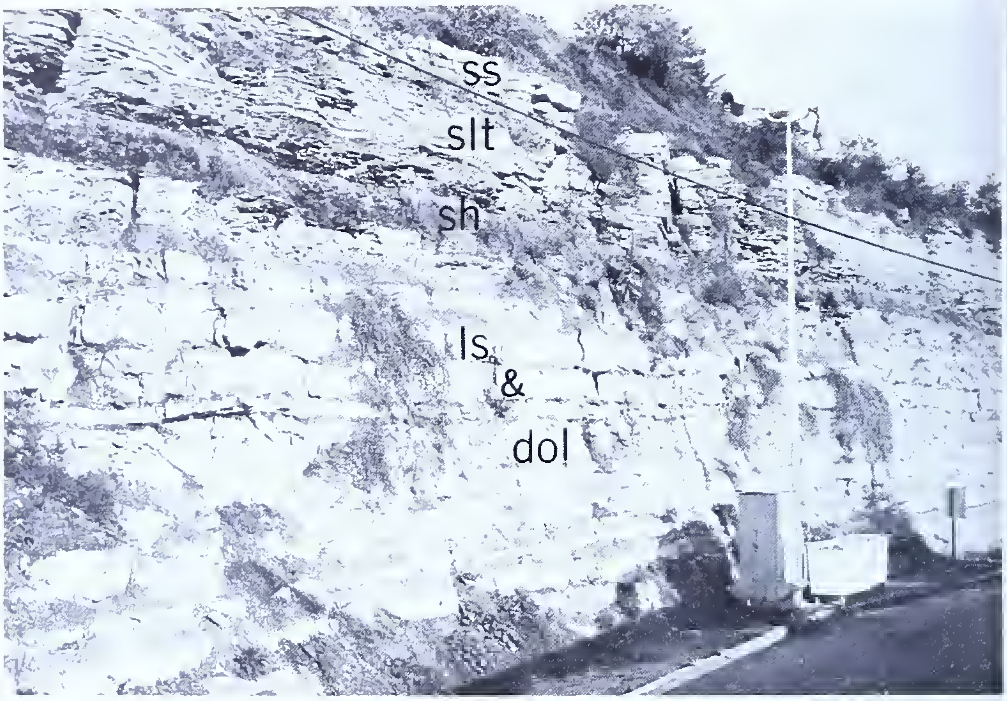


Figure 9. Interbedded limestone (ls) and dolomite (dol) of Benwood carbonate layer overlain by shale (sh), siltstone (slt) and sandstone (ss). Contrast the undulating layering of the carbonate rock with the more planar layering of the sandstone (Locality 23—Route 19 and Gilkeson Road).

more abundant type, particularly in the southern half of the county, where they are so fine-grained that the rock breaks with curved (conchoidal) surfaces. Only with a microscope can the individual grains be seen. Most individual layers are less than two feet thick and are interbedded with a few inches to a few feet of shale or claystone. The carbonate rocks behind Howard Johnson's Restaurant at Locality 23 (Figure 9) are fresh-water type. Other exposures may be seen along Interstate Route 79 between Washington, Pennsylvania and Bridgeville.

Marine carbonate rocks are also identified by the fossils they contain. These rocks represent times in geologic history when seas covered the Pittsburgh area and the inhabitants of the county were the brachiopods (lamp shells), gastropods (snails), pelecypods (clams), and crinoids (sea lilies) that lived at the bottom of the sea. Today their shells are preserved as fossils in the rock. A freshly broken surface of a marine carbonate rock may range from light gray to nearly black depending on the amount of clay and carbon that is in the rock. Silt and sand are also common impurities. These carbonate layers are thinner and generally more fossiliferous than the fresh-water carbonates. Commonly they consist of one or two layers six inches to three feet thick whereas a unit of fresh-water carbonate may be tens of feet thick. The marine carbonate rocks are best exposed in the northern part of the county.

The most significant marine carbonate rock because of considerable geographic extent, fossil content, and value as a marker bed is a two- to three-foot thick layer called the Ames limestone. The geologic interest of many Pittsburgh residents was first kindled by collecting fossils that weather out of the clay bearing Ames limestone. A good collecting

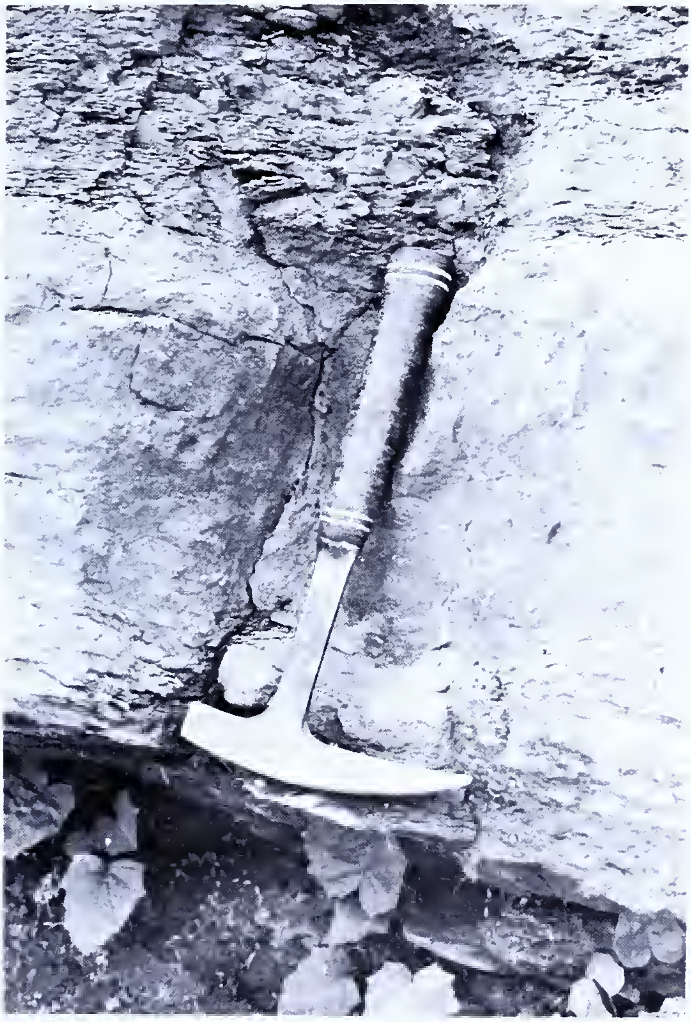


Figure 10. Ames limestone at Brilliant Cut. White specks in limestone are fossil shell fragments. For location of Ames at Brilliant Cut see Figure 31. (Locality 38—0.2 miles east of junction of Washington and Allegheny River Boulevards).

locality of the Ames is along Route 22 across from the Burke Glen swimming pool between Murrysville and Monroeville (Locality 42). There it stands out as a resistant ledge in a red claystone. Another locality is at Brilliant Cut on the Allegheny River Boulevard just east of the junction with Washington Boulevard in Highland Park (Locality 38). Figure 10 is a photograph of the Ames at Brilliant Cut and the location of the Ames is shown in Figure 31.

Carbonate rocks may be either clastic or non-clastic. Non-clastic carbonates are composed of tiny crystals that slowly settle out of water and accumulate on the bottom of a sea or a lake. The crystals are buried and preserved at their site of origin. Clastic carbonate rocks, in contrast, are made of carbonate fragments cemented together by carbonate crystals. The fragments may consist of shells or they may be formed by currents ripping pieces of carbonate from the floor of the lake or sea and moving them about before they are cemented into rock. Both the clastic and non-clastic varieties are found in the fresh water and marine carbonate rocks. On a weathered surface, the individual clastic fragments may be seen in a matrix of very fine, indistinguishable crystals. On a fresh surface, however, the rock may appear homogeneous. The slightly different resistance of fragment and matrix to weathering results in differential weathering which emphasizes the texture of the rock.

COAL

Although coal represents only a small percentage of the total rock exposed, it has been and remains economically the major mineral resource of the Pittsburgh area. Because of coal's significance, its economic geology will be discussed in Section IX; in this section the appearance of coal at outcrop and the origin of coal is considered.

A fresh surface of coal usually reveals alternating shiny black and duller black bands whereas a weathered face may appear uniformly gray. Coal in western Pennsylvania has a very blocky pattern of splitting which enables one to collect cube-like chunks several inches on a side.

More than 20 separate coal seams are exposed in Allegheny County. They range in thickness from a fraction of an inch to more than nine feet. The Pittsburgh coal seam, which occurs primarily south of the Ohio River and east of the Allegheny River, is the world's most famous coal because it is mined over an extensive area of 6,000 square miles. The Pittsburgh seam may be examined in outcrop behind the stores on Route 51, 0.4 mile south of the junction of Route 88 (Locality 27). Another good exposure occurs along the Ardmore Avenue entrance to the Parkway East (Locality 40).

Coal is formed by the accumulation, alteration, and compaction of plant debris in a swamp. When examined microscopically, the plant fragments making up the coal can be seen. Plants are compounds of carbon (C), oxygen (O), hydrogen (H), and nitrogen (N) and when some of the hydrogen, oxygen and nitrogen are driven off, the carbon remains concentrated as coal. The process of coal forming is complex. Plant material accumulates for centuries and bacteria, fungi, and organic acids decompose the material into peat. Eventually the peat is buried below layers of sediment whose weight compacts the peat first to brown coal or lignite and then to the bituminous coal or "soft" coal as in the Pittsburgh area. The shiny black layers of the bituminous coal are called anthraxylon or vitrinite and are derived from the wood of plants. The duller layers are called attritus or micrinite and consist of finely divided plant materials that are more resistant to decay than the woody parts.

VARIETY OF ROCKS

Examination of one or two outcrops will show that rocks are not commonly "pure" types, such as pure sandstone or limestone or coal, but that many rocks are in reality mixtures of different kinds of rocks. A black shale indicates significant amounts of carbon mixed with the clay thus making the rock a carbonaceous shale instead of a pure shale. A complete transition may exist from a finest textured shale to the coarsest conglomerate, and from a wholly non-clastic rock to a totally clastic one. The pure rock types are merely points of reference on a continuous line of rock types. Just as steps are cut into a steep slope to make the ascent easier, the pure rock types are "stepping-stones" in the very wide range of rock types. Figure 11 shows the "pure" and intermediate rock types that occur in Allegheny County.

ENVIRONMENTS OF DEPOSITION

An important aspect of the rocks of Allegheny County is the environment in which they were deposited many millions of years ago. Each rock type, whether pure or transitional, represents accumulation of sediment under certain environmental conditions. To have deposition, a supply of sediment is needed and an area of accumulation is required. The sedimentary supply may consist of grains of quartz sand or silt size which when preserved and turned to rock makes sandstone or siltstone. An influx of clay may be compacted and hardened into shale or claystone, calcite crystals may become limestone, and peat may become coal. The area of accumulation may be a stream channel, a river flood plain, the floor of a lake, a swamp, a delta, or the open sea. By examining modern sedimentation in lakes, the deltas like the Mississippi, and in coastal regions off Florida, the geologist is learning what sediments accumulate in various environments. He applies this knowledge to rocks, the ancient sediments, to determine their past environments of deposition.

When the rocks of Pittsburgh were being deposited as sediments, the topography was much different from today's well dissected plateau with

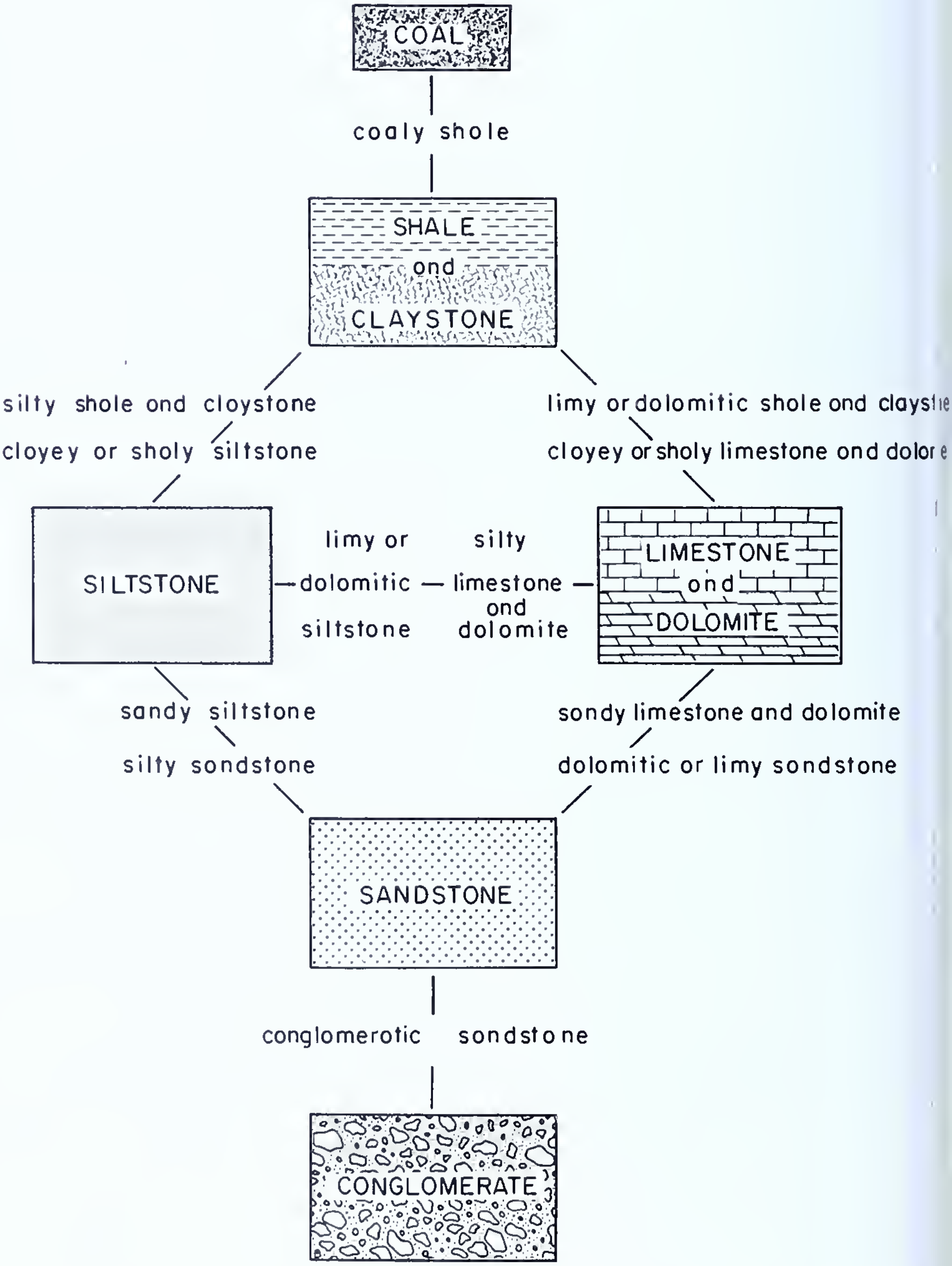

COAL
coaly shale
SHALE and CLAYSTONE
silty shale and claystone
clayey or shaly siltstone
limy or dolomitic shale and clayst
clayey or shaly limestone and dolo
SILTSTONE
limy or dolomitic siltstone
silty limestone and dolomite
LIMESTONE and DOLOMITE
sandy siltstone
silty sandstone
sandy limestone and dolomite
dolomitic or limy sandstone
SANDSTONE
conglomerotic sandstone
CONGLOMERATE

Figure 11. "Pure" and transitional rock types of Allegheny County.

steep-sided valleys. At that time, approximately 300 million years ago, Allegheny County lay very close to sea level, sometimes slightly above and at other times slightly underwater. Figure 12 shows the probable geography of Pennsylvania during a part of the Pennsylvanian Period, that period of time when the exposed rocks of the Pittsburgh area originated. Rivers carried sand, silt, and clay eroded from the mountains across an alluvial plain, a plain of deposition, to the shoreline in western Pennsylvania. In the western half of the State the land was a low coastal plain that sloped very gently westward to the sea. Within the near-shore area, where Allegheny County is now located, five distinct environments of deposition were present. Offshore, in the open-water environment, marine rocks such as the Ames limestone were formed (Environment A of Figure 12). Along the shore extended a swamp environment of tall trees, ferns, and lush vegetation (Environment B) where the Pittsburgh coal seam began its long history. The lake environment (C) was located up the coastal plain slope behind the swamps and in these lakes were formed the fresh-water carbonate rocks. The other two environments were the result of stream action. Environment D represents the sand and silt deposited in the stream channel during normal flow and also the silt and clay dumped on the flood plain during times of flood. When a stream flows into a lake or sea, it loses velocity and the sediments being carried are deposited at its mouth. The sediments are gradually built out into a lake or sea to form a delta (Environment E) unless the open-water currents are strong enough to remove the sediments as they are added.

Open-Water Environment

The open water environment includes the sea and any large associated embayments; shale and limestone are the main representative rocks, with lesser amounts of siltstone and sandstone. Clay, silt, and sand are carried from the land into the open water by streams. Most of the coarser clastics, the silt and sand, are deposited in the stream and delta environments, leaving clay with some silt and sand to be sorted by the currents of the open water. Thus, the clastic rocks of open water are commonly shale, silty shale, and siltstone. Limestone is deposited in areas that are not receiving much clastic sediment. The limestone may form by precipitation of calcium carbonate from the water or by accumulation of calcareous shell fragments cemented by ground up shell material, or usually by a combination of both processes.

Most rock types are not restricted to one environment of deposition, and the rocks of Pittsburgh are no exception. It is often difficult, even

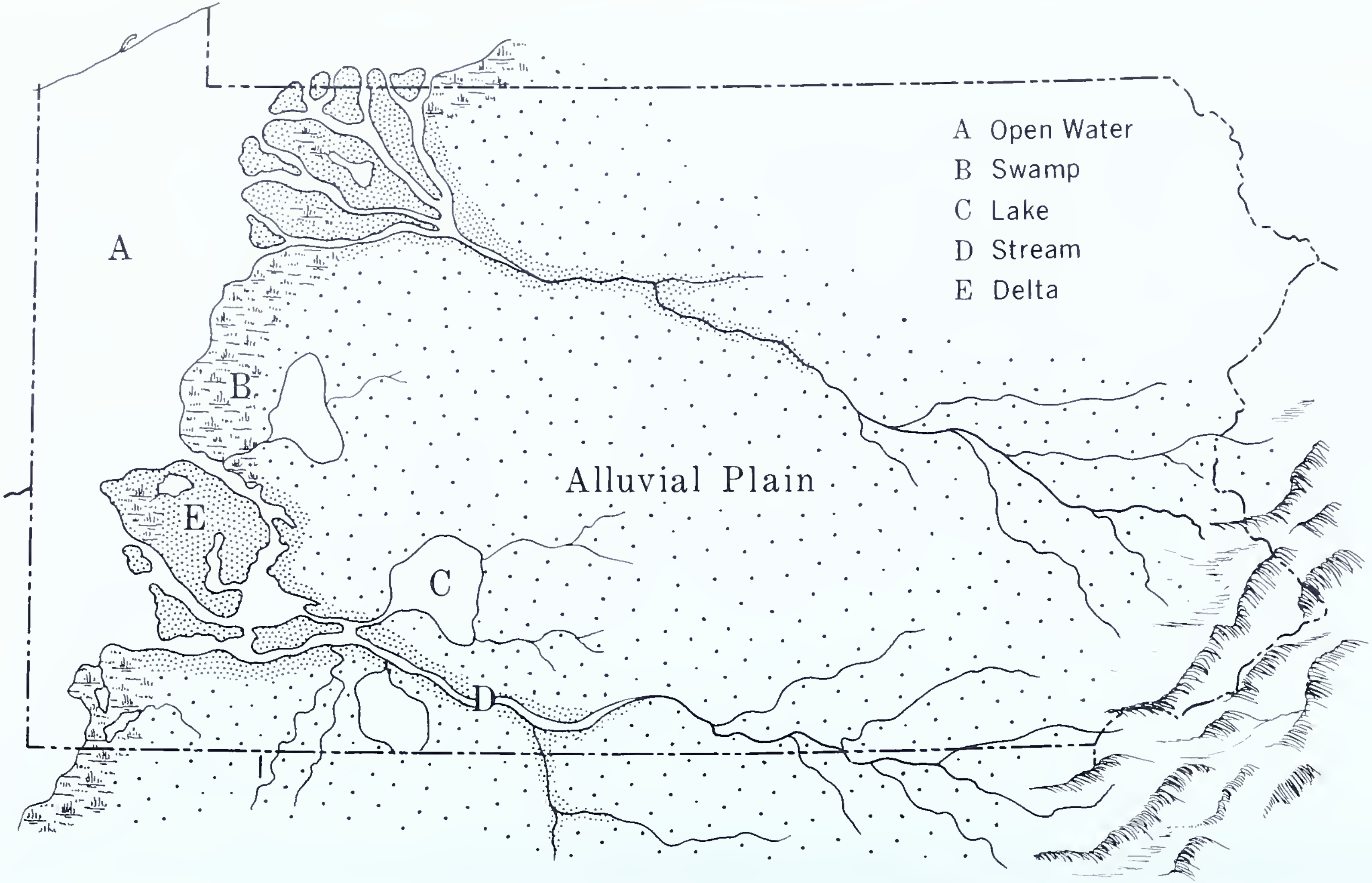


Figure 12. Probable geography of Pennsylvania when rocks of Allegheny County were deposited.

for a geologist, to determine the environment in which a particular limestone, shale, or sandstone was formed. The best evidence is afforded by preserved fossils. If the rock contains marine fossils such as the cup coral, *Lophophyllidium* or the brachiopod, *Neospirifer* (Figure 45), or crinoid stems, (Figure 48) then the rock is undoubtedly of open-water origin. The Ames limestone is proved to be an open-water limestone because it contains these fossils.

Other limestones with marine fossils are the Pine Creek limestone just above eye level on Route 8 immediately north of Etna (Locality 13) and the Brush Creek shaly limestone which is exposed at the south end of the Sewickley Bridge (Locality 4).

A dark gray open-water shale containing well-preserved marine fossils plus an abundance of pulverized shell fragments is exposed on the Ohio River Boulevard between Glenfield and Haysville. The one-foot thick shale is at road level at the crest of the hill (Locality 5).

Where fossils are not present, the depositional origin of sedimentary rocks becomes problematical. Other guides such as layering characteristics, texture, and regional shape of the layer must be used. In siltstones and sandstones evenness of layering and uniform thickness over considerable distance are indicators of open water deposition, whereas lenticular layering is characteristic of deposition on land. Sandstone or siltstone formed in open water will tend to have a texture that shows better grain-size sorting than one from a stream or delta habitat. Good sorting means that a sandstone has a narrow range of grain-size variation, perhaps all fine-grained sand or all coarse-grained sand, whereas a poorly sorted sandstone may contain both fine and coarse grains. The interbedded siltstones and shales on Route 22 just west of Murrysville at the boundary of Allegheny and Westmoreland Counties (Locality 44) may be of open water origin because of the even layering, consistent thickness and very fine texture of the siltstone. Another location is along the railroad tracks north from Allison Park station which is just off Route 8 (Locality 10). Here a sandstone layer approximately 15 feet above a coal seam has characteristics similar to those on Route 22. In addition, one large block of sandstone that has fallen exhibits fossil ripple marks which look like an irregularly corrugated board. Modern ripples may be seen forming along the Atlantic coast beaches where breakers and currents crenulate the sand. Ripples also occur in freshwater lakes and can often be observed in very shallow water sand along the banks of the Monongahela River at the Pittsburgh Triangle.

Most of the open-water rocks occur in the northern half of Allegheny County. The reasons for this are discussed in Section IV.

Swamp Environment

Swamps and marshes are bodies of shallow, quiet water or areas of low wet ground occupied by abundant plant life. They may be small and isolated or they may extend many square miles along low coastal areas (Environment B of Figure 12). Both small and large swamps were present intermittently in the Pittsburgh area millions of years ago when the rocks now at the surface were deposited. The plant material of the swamp consisted mainly of tall trees called *Lepidodendron, Calamites* (Figure 50), and *Cordaites* (Figure 49) which are related to modern ferns and club mosses. The branches and leaves of these plants partly decayed, were converted to peat, and eventually were transformed into bituminous coal. The extensive coal seams which have been mined underground and stripped at the surface probably represent enormous coastal swamps whereas the thin restricted coal seams may have originated in much smaller bogs located on deltas.

Thick coal seams like the Pittsburgh coal are not simply one homogeneous layer. They are generally divided into several coal beds, each bed separated from the one above and below by a fraction of an inch to several inches of impure coal or carbonaceous shale called parting. The Pittsburgh coal has two major divisions; a lower main bed that is mined and an upper unmined sequence that forms the roof of a mine and hence is called the "roof coal". The roof coal sequence may contain several thin coals and interbedded shales. Figure 13 shows the detail of the Pittsburgh coal main bed and roof coal near Bentley Drive in the City of Pittsburgh. The coal at this locality is no longer well exposed. Roof shales are potentially good hunting grounds for carbonized fossil leaf impressions.

The presence of partings and roof shales separating individual coal beds can be explained in several ways. Sluggish streams meandering through the peat swamp deposit their load of clay and silt during floods and temporarily interrupt the formation of peat. At other times a slight rise of the sea or lowering of the land drowns the peat swamp, and deposition of open-water silt or clay rather than peat occurs. The presence of another coal overlying the shale or silty shale indicates a return to swamp conditions and peat formation.

Lake Environment

Behind the coastal swamps and extending for many miles inland was a flat lowland with numerous large and small water-filled depressions. Imagine a coastal plain similar to that of southern New Jersey with its inland lakes a few tens of feet above sea level located 20 or 25 miles from the coast. Picture this environment in the Pittsburgh area of millions of years ago, replace the New Jersey sand with mud and clay, increase the size of the lakes, and you have a concept of the lake environment.

The rocks of the lake environment are fresh water carbonate, shale, and claystone. All are fine-grained rocks deposited under conditions of low energy that prevailed in quiet or slowly moving water. The size of the ancient lakes influenced the characteristics of the sediments. Deposits of small lakes are primarily shale and claystone and may show a transition to swamp conditions. Large lakes, however, were less affected by the clastic sediments, and carbonates were also precipitated. Alternation of shale and carbonate rock in a large lake deposit may be seen at

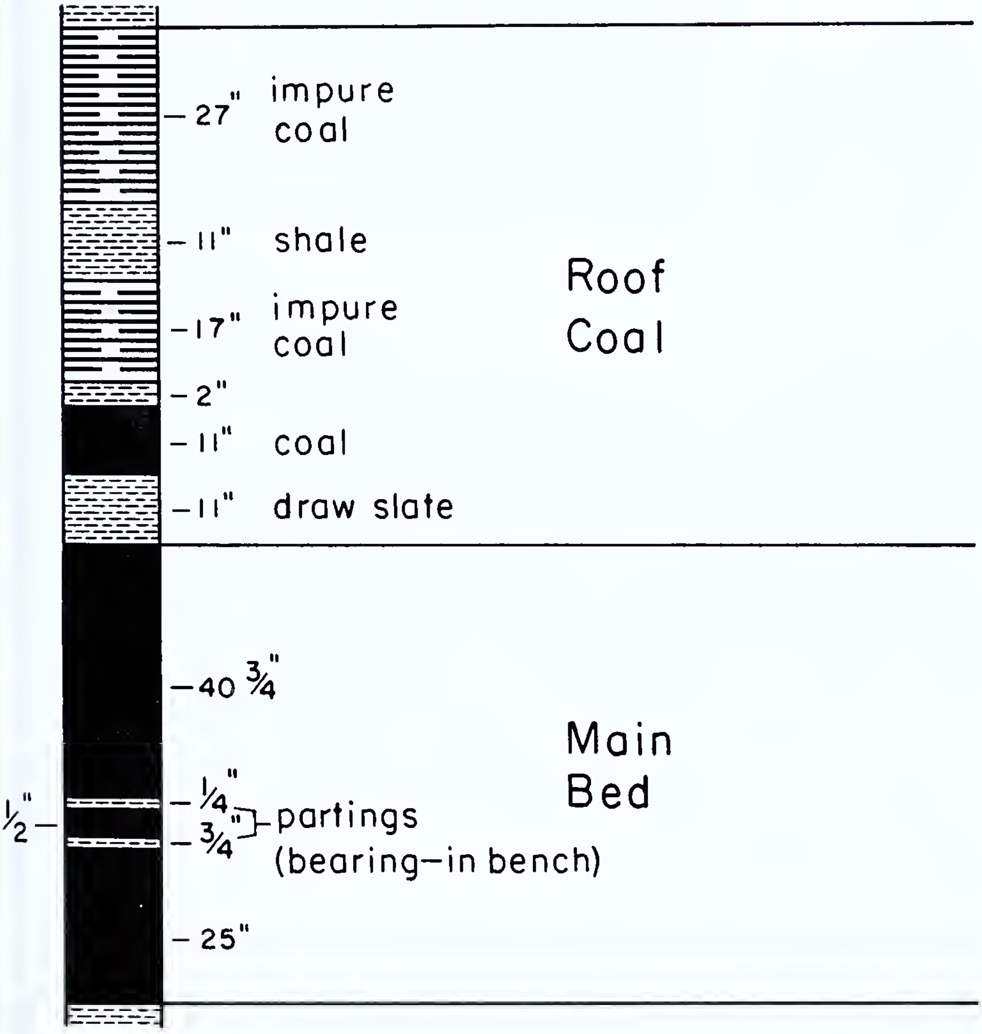


Figure 13. Detailed layering of Pittsburgh coal seam, Bentley Drive, Pittsburgh. Outcrop no longer exposed (Adapted from Johnson, 1929, p. 90, 93).

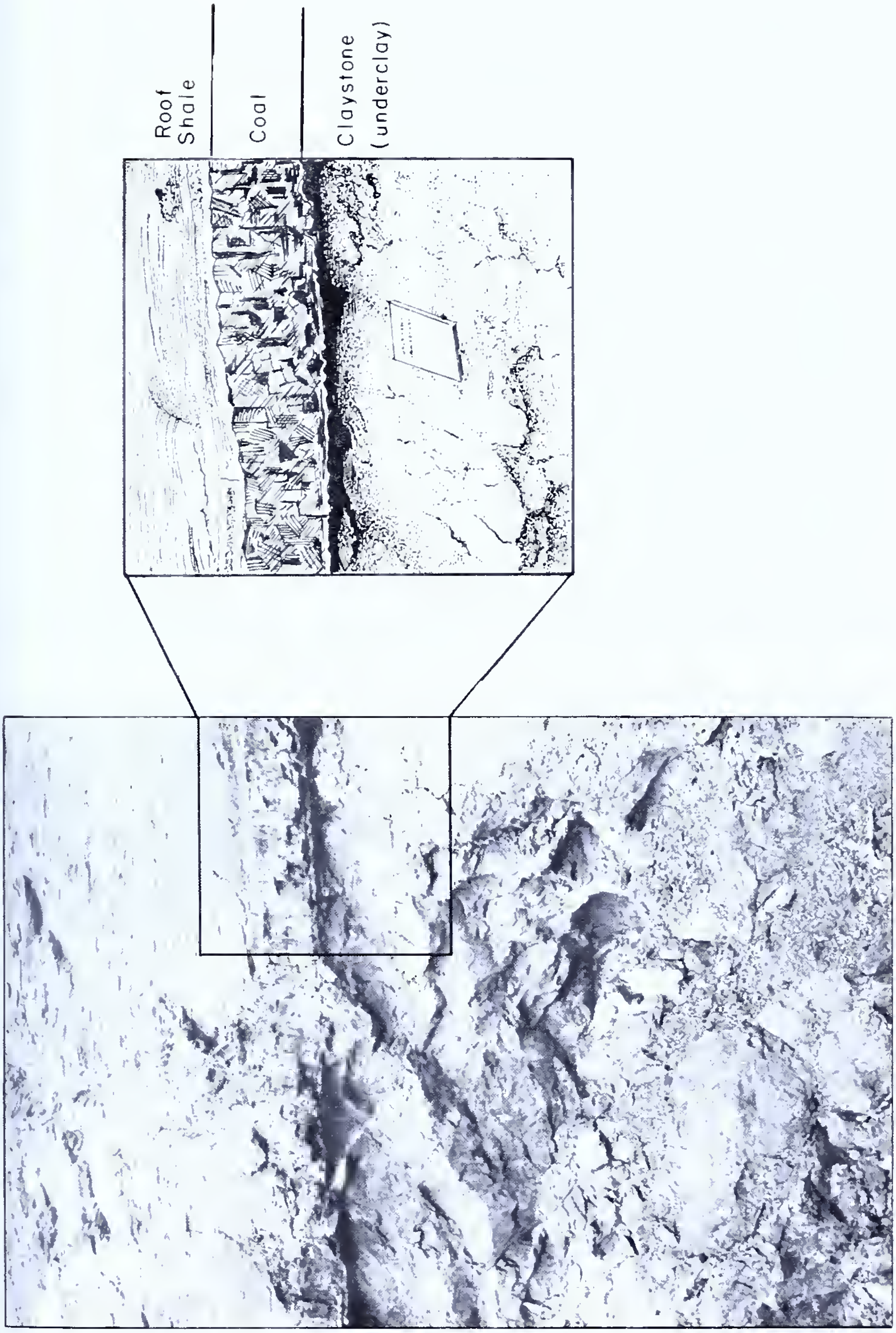
Howard Johnson's restaurant on Route 19 (Locality 23). There, carbonate precipitation was periodically interrupted by influx of large volumes of clay into the lake.

In science, many problems exist for which there are no answers or the answers are vague and incomplete; the Pittsburgh area has its share of unsolved geological problems. One problem is presented by the dolomite layers interbedded with the fresh water limestones. Limestone can form in fresh water and normally saline (salty) waters of the sea, but dolomite is believed to require excess salinity. To obtain high salinities in a lake, the amount of water lost by evaporation must exceed the amount of water entering the lake. Evaporation is high in a dry or semi-arid region like that in which the Mediterranean Sea exists, so perhaps a semi-arid climate is indicated for formation of dolomite. If a dry climate is necessary for dolomite, then how do we explain the presence of lush, damp, coastal plain coal swamps which probably existed at the same time that dolomite was forming in the lakes?

A second problem that exists is the origin of a soft, light-colored type of claystone associated with the fresh water rocks. These claystones, ranging from several inches up to 15 or 20 feet thick, underlie the coal seams and thus are called "underclays". They are without layering and contain fossil plant rootlets, the rootlets perhaps being responsible for destroying any initial layering that may have been present. For years disagreemnt has centered around whether the underclay is a fossil soil which was formed prior to the development of a coal swamp or whether it represents a fine clay deposited as a fresh-water lake became filled with sediment. The first origin implies that the underclay represents an erosional surface or a surface of non-deposition where soil formed. If this is truly how the underclay formed, then it is an example of a hiatus or a gap in deposition. The second origin signifies no interruption of deposition but a gradual transition from lake environment to peat formation as clay particles settled out of suspension in the quiet water. In both cases the clay and the associated fresh water carbonates formed in the lake environment which was located behind the swamp environment. Figure 14 shows a coal seam about one foot thick; it is underlain by a massive, non-bedded claystone, an underclay, and it is overlain by a roof shale exhibiting closely spaced layering or lamination.

Stream Environment

The stream environment encompasses all the deposits of a river valley and can be divided into two broad categories: those deposits of the stream channel itself and those of the flood plain which is covered with water when the stream overflows its banks.


Roof Shale
Coal
Claystone (underclay)

Examine a topographic map of the Pittsburgh area. The brown contours represent lines of equal elevation above sea level. Steep slopes are indicated where the lines are closely bunched, and gentle or flat land is shown by only a few widely-spaced contours or no contours at all. In hilly Allegheny County the most extensive flat areas are on the tops of hills or located along the borders of the major rivers. The flat areas just above river level are the flood plains where most of the county's heavy industry is concentrated. Some towns, such as Aspinwall and Sharpsburg lie on the Allegheny River flood plain; parts of McKeesport are situated on the Monongahela and Youghiogheny River flood plains. Islands within the channels of the Allegheny and Ohio Rivers are widely used for industrial purposes. One of the largest, Neville Island, also contains residential area. With human activity so concentrated along the rivers, floods can be disastrous. Past floods prompted construction of numerous dams on the Allegheny and Monongahela Rivers and their tributaries to minimize flooding.

Information derived from studies of modern streams is used to identify and locate ancient stream deposits. The geologist examines the shape of the modern stream, that is the configuration on a map and on a cross-section; he studies the kind of sediment deposited in the channel and on the flood plain and he looks for specific characteristics such as special kinds of layering and variations in grain size.

A map view is a birdseye view of a river valley where the stream and its flood plain appear as a long, narrow, winding path like a relaxed shoestring. Sediment that accumulates in the stream channel is forced to accept the shape imposed upon it by the boundaries of the channel. In a similar way, the sediment of the flood plain is restricted by the valley walls.

In cross-section a stream valley looks like a trough. Figure 15 is a cross-section through the Triangle of Pittsburgh showing the valleys of the Allegheny and Monongahela Rivers. The topographic relief of the valleys, that is the elevation of the hilltops (about 1200 feet) above that of the valley floor (700 feet) is about 500 feet. These two valleys are not merely low areas where the rivers flow. Instead, they are low areas because for tens of thousands of years the rivers have flowed through them. The rivers created the valleys and have acted as great shovels eroding away the rock that once filled the valleys. Two already familiar rock units, the Pittsburgh coal and the Ames limestone are shown on the cross-section. These units were in existence millions of years before the appearance of the rivers and extended completely across the area as indicated by the dashed pattern.

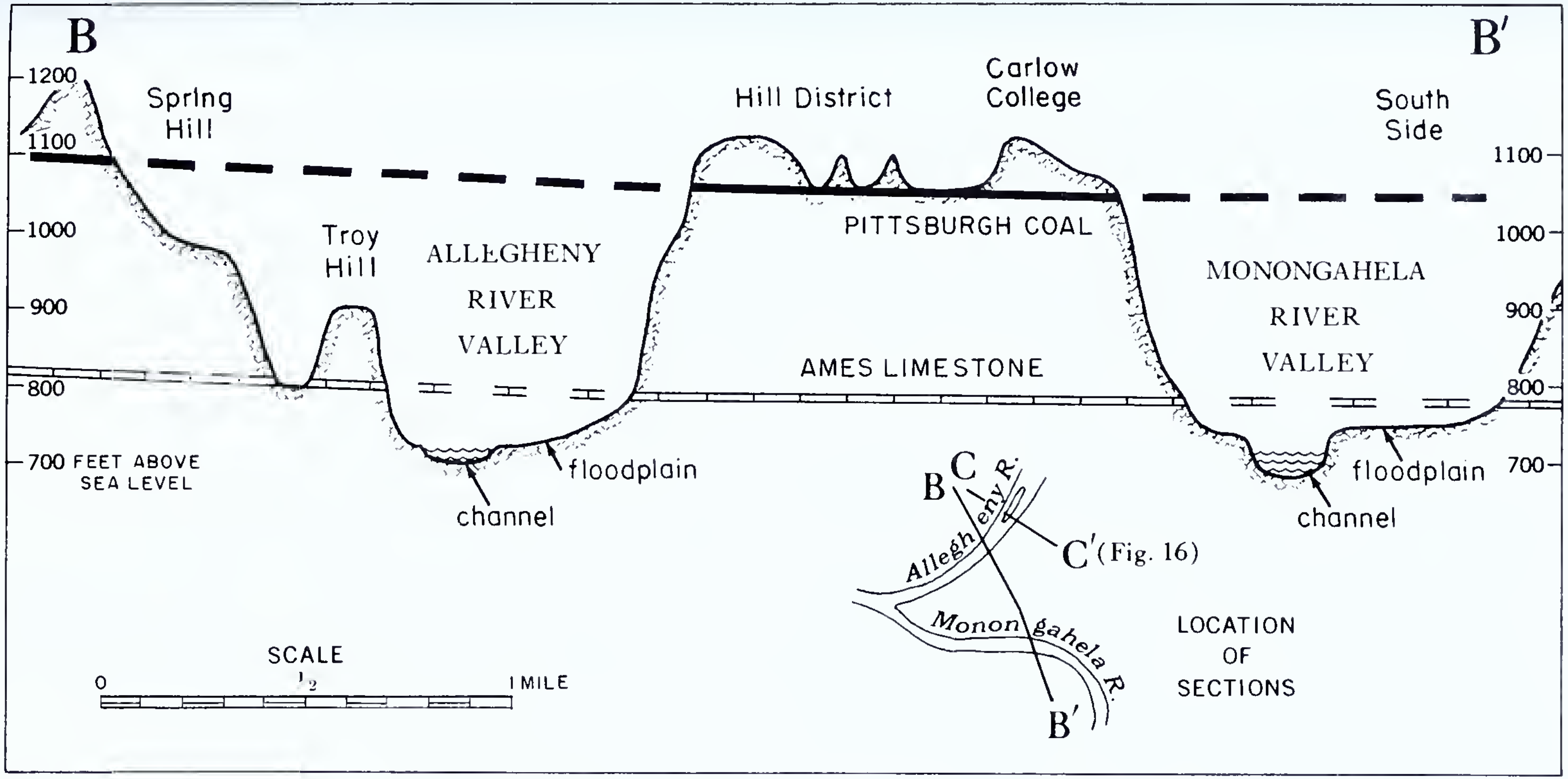


Figure 15. Section through the Pittsburgh Triangle showing the erosional valleys of the Allegheny and Monongahela Rivers.

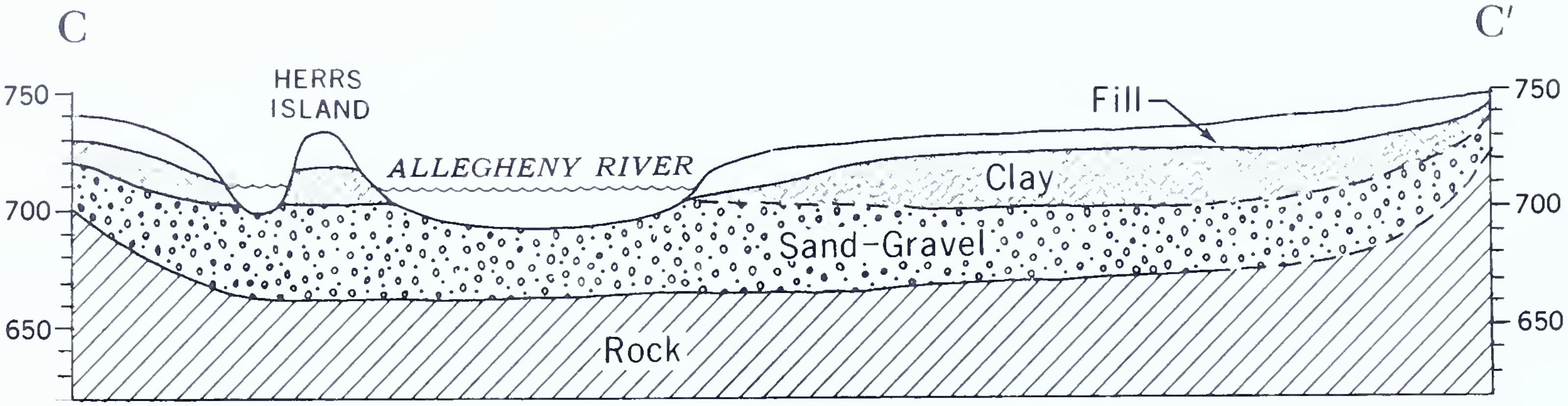


Figure 16. Section across Allegheny valley at lower end of Herrs Island, Pittsburgh. Location of section is shown on Figure 15. (Adapted from Adamson and others, 1949, Fig. 3).

The formation of valleys emphasizes the stream's erosional aspects, but streams also have a depositional nature. Figure 16 is a section across the Allegheny valley at the lower end of Herr's Island. Deposited at the base of the scooped out valley is approximately 35 feet of sand and gravel; above that is about 20 feet of clay, and at the very top is "fill", the sediment deposited by the river during times of flood plus the material man has added to build up the surface. The main difference between the material deposited by the river and the material that has been scooped out is that the river sediment is unconsolidated or not cemented into rock whereas the scooped out material was cemented into rock millions of years ago. Because of the unconsolidated nature of sand and gravel, it is dredged from the river, then cleaned, sorted, and used in the builing industry. Sand and gravel are more porous and permeable than rock because the space between grains is not filled with natural cementing material. Therefore, water can circulate through the unconsolidated sand and gravel with much more ease than through a sandstone or conglomerate. Many buildings in downtown Pittsburgh are air conditioned with water obtained from wells drilled into the sand and gravel. The gravel exists in the Allegheny River because it was washed out of melting glaciers which lay to the north of Pittsburgh tens of thousands of years ago.

The contact between the unconsolidated and the consolidated material is another example of an erosional surface or hiatus. With respect to time, the unconsolidated material is less than one million years old but the rock is approximately 300 million years old. The surface of contact therefore represents a time period of more than 299 million years duration. Structurally, with respect to shape and form, the erosional surface shows a "cut-and-fill" relationship where river erosion has "cut out" or excavated the existing rock and later "filled" the vacancy with sediment carried in its channel and flood plain.

The distinction between sediment and rock, while it differentiates modern stream deposits from ancient rock, is of no value in detecting ancient stream deposits. In these cases the ancient stream deposits have been converted to rock and rock is therefore located on both sides of the erosional surface. The structural cut-and-fill relationship, however, may still be observed and numerous "fossilized" stream channels are well exposed in Allegheny County. One fine exposure showing ancient cut and fill is located just north of the Montour Run exit of the Parkway West. The outcrop is about one-half mile long beginning at the Parkway and extends east to the bend in the road (Locality 19). Figure 17 illustrates the features to be seen in the eastern 1,000 feet of the outcrop. Exposed is about 50 feet of rock in two sections separated by a bench or

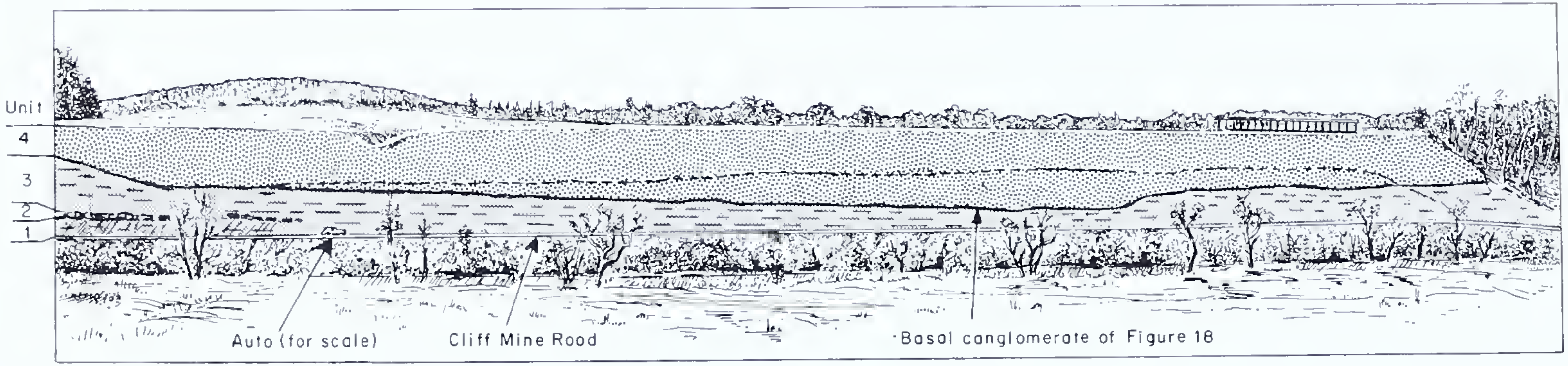


Figure 17. Cliff Mine Road ¼ mile north of Parkway West. Channel sandstone with basal conglomerate cuts out underlying claystone and shale (Locality 19—lower Casselman and upper Glenshaw Formations).

Unit 4—Channel sandstone.

Unit 3—Gray to gray-red claystone underlain by dark gray shale containing limestone nodules.

Unit 2—Ames limestone.

Unit 1—Red shale (Pittsburgh reds) covered by gray shale talus.

level terrace. The lower 12 feet just above road level are reddish shale that is covered by gray shale talus. Above the talus at the western end of the diagram is the shaly, fossiliferous, greenish-gray Ames limestone about two feet thick. The Ames probably extends the length of the outcrop but it is covered by talus. Overlying the Ames is a dark gray shale containing limestone nodules which changes upward into gray and gray-red claystone. Above the shale and claystone is a sandstone which represents deposition in a stream channel. Note that the sandstone unit is bowl or trough shaped; its lower boundary with the shale or claystone is sharp, uneven, and most important, the sandstone extends down and replaces first the claystone and then the shale. The replacement indicates cut and fill in that the shale and claystone were eroded away by the stream which later deposited the sandstone. The boundary between the shale and the sandstone is an erosional surface.

Beside cut and fill, a stream exhibits certain characteristics of deposition that are helpful in identifying its origin. These features are rock type, distribution of grain size, and the type of layering. Stream channel deposits are usually sandstone and siltstone with the coarsest material at the base of the channel. Commonly the bottom part of the channel contains sandstone or even conglomerate which grades upward into finer sandstone and eventually to siltstone or shale at the top of the channel. The channel deposit at Montour Run mentioned above has a medium-grained sandstone at its base and included in the sandstone are seams of coal, fragments of shale and claystone, and plant impressions. This basal layer is a shale-pebble conglomerate (Figure 18). Above the conglomerate the sandstone becomes finer grained and the fragments diminish upward. Another basal conglomerate can be observed in a very large channel deposit along Monongahela Boulevard near Kennywood (Figure 7).

The upward decrease of grain size of a stream channel sandstone commonly reflects the gradual decreasing velocity of flow of a stream throughout its history. In its early stages a stream has its greatest velocity and can transport and deposit relatively coarse material. Shale and coal fragments can be ripped from a stream bed or bank and be incorporated into sand being carried downstream. In later stages the velocity slows because the gradient or slope along which the stream is traveling has become increasingly flatter and the material that is carried and deposited gets smaller and smaller. Thus, the change from coarse-grained material at the base of a channel deposit to fine-grained material at the top indicates the decreasing velocity of a stream.

Some sandstones show a fine layering or lamination positioned at an angle to the main layering (Figure 19). This type of structure is called

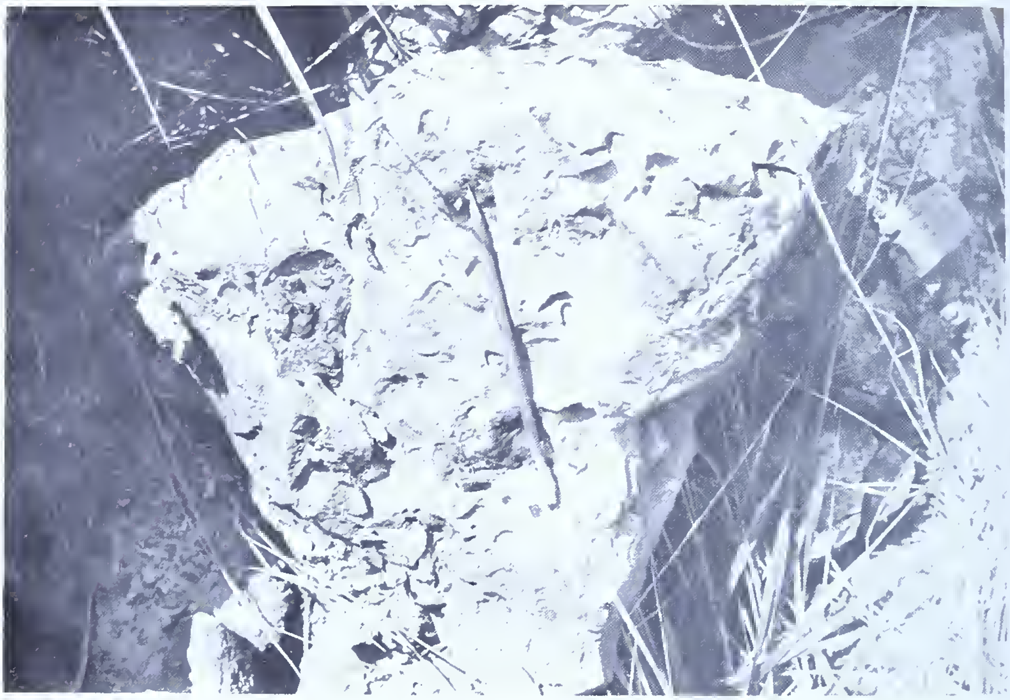


Figure 18. Basal conglomerate from unit 4 (channel sandstone) of Figure 17.

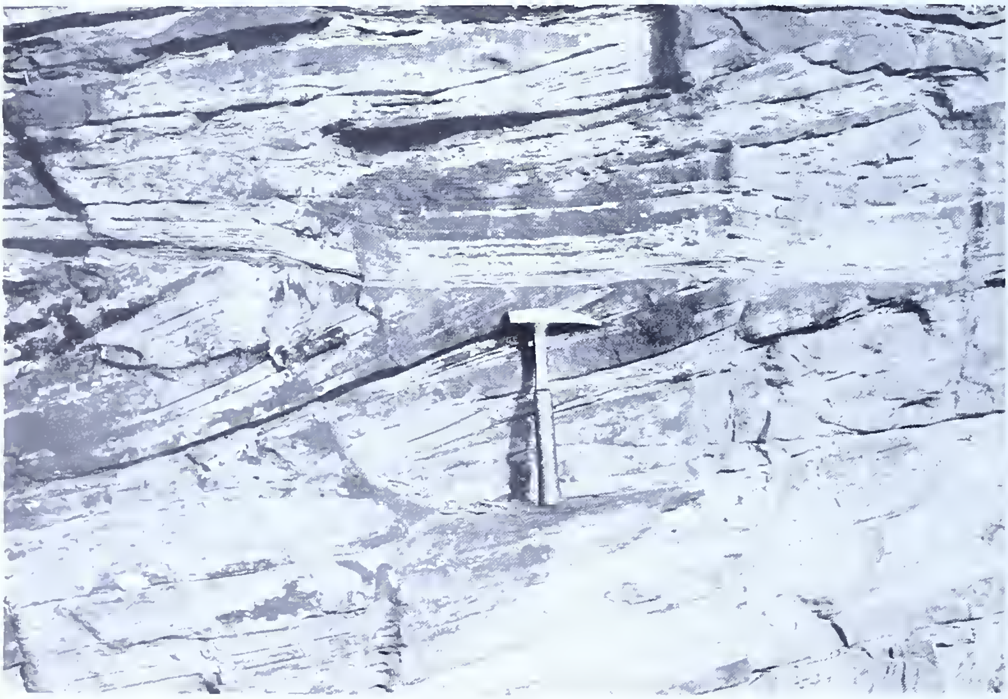


Figure 19. Cross-bedding (at hammer head) at angles to regular layering. (Locality 6—a lower Glenshaw sandstone in cliff along Penn-Central Railroad 900 feet southeast of Jacks Run and Ohio River.

cross-bedding. It is the result of current action of water and is particularly well developed in stream channel sandstones, athough it occurs in sandstones of many environments. In building a sand bar in a channel or along the shore where the stream valley bends, the sand is carried over the bar and dropped on the downstream slope. A continuation of this process leads to successive laminations built forward which are inclined to the main surface of accumulation. The direction that the cross bedding slopes is the general direction of current flow meaning that cross beds are usually inclined downstream.

Deposits of the flood plain are finer-grained and more even layered than channel deposits. They are the thinly layered clay and silts that settle out of the slowly moving sheet of water which overflows the stream banks. The resulting shales and siltstones are commonly much thinner than the channel sandstones and siltstones. Figure 20 shows very fine layering of micaceous flood plain silty shales above the Pittsburgh coal along the eastbound cloverleaf to the Parkway East at Ardmore Boulevard (Locality 41).

Over many thousands of years a stream moves constantly back and forth across its valley depositing sediment in one place while removing it from another. Sand and gravel may accumulate in a stream channel

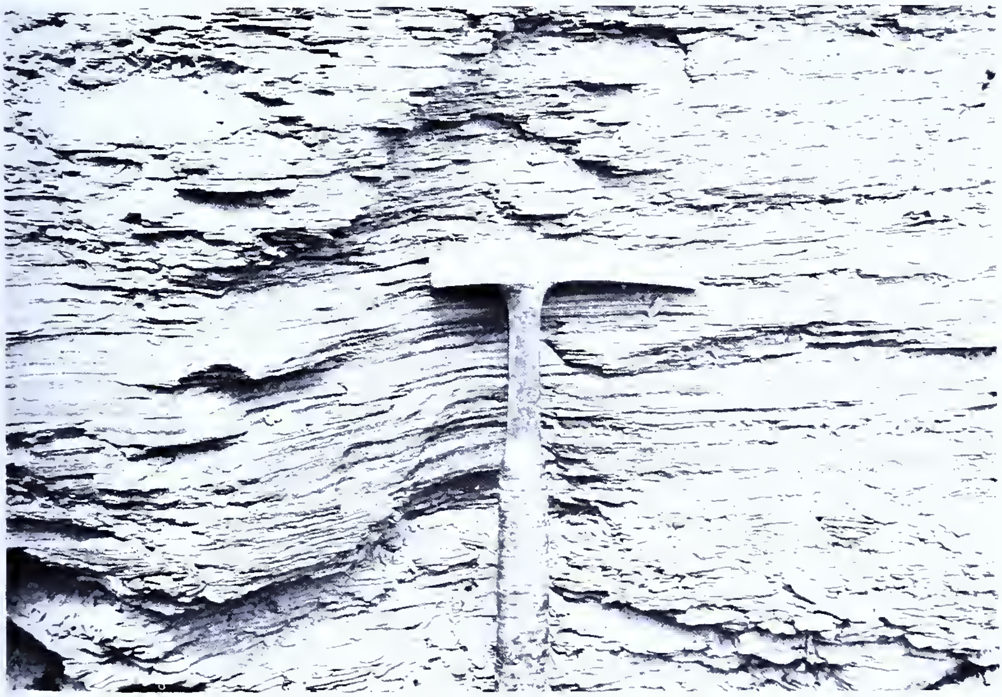


Figure 20. Laminated floodplain silty shale in lower Pittsburgh Formation. (Locality 41—eastbound cloverleaf at junction of Ardmore Boulevard (Route 30) and Parkway East).

only to be eroded away at a later time. Evidence of a stream's change of position through time can be excellently observed along Route 906 on the east side of the Monongahela River 2.4 miles south of the Allegheny-Westmoreland County line. An almost uninterrupted sequence of 100 to 200 feet of sandstone, shale, claystone and minor amounts of limestone is exposed between the village of Webster and Monessen (Locality 35). Plate 2 (in pocket) illustrates part of the road cut along Route 906. Figure A of the plate is a sketch of the complete hillside and the outlined portion refers to that part of the hillside which is diagramed and interpreted in Figures B, C, and D. Figure E shows the exact location of the locality.

The rock types shown in Figure B are sandstone, claystone, shale, and coal. Interpretation of the events which explain the vertical and horizontal changes of rock type is given in Stages I to VI of Figure C. Unit 1 of Figure B and C is a reddish to grayish claystone into which a valley has been cut and the contact between the claystone and the rocks filling the valley is an erosional surface. At the left or northeast end of Figure B, the erosional surface is most evident where two thin sandstone layers and an intervening shale-siltstone layer have been abruptly cut off. The initial deposit in the claystone valley was unit 2, a massive sandstone, one in which no layering is seen. Lack of layering indicates relatively rapid deposition. Stage I of Figure C shows the claystone valley and the massive sandstone unit 2 deposited in it.

As sediments build up in the valley, the gradient of the stream diminishes and the velocity of flow decreases causing the stream to meander or curve. Meandering resulted in the stream shifting its position to unit 3, which lies northeast (left) of unit 2. In the center of unit 3 is a layered sandstone, but toward the edges of the unit the sandstone changes to a silty shale. The change occurs, not by cut and fill, but by gradation from one rock type into another. The sandstone is a channel deposit and the shale represents accumulation on the flood plain. Stage II of Figure C indicates that the contact of unit 3 with unit 2 is erosional because the stream at 3 has removed part of its previous channel at 2. Close inspection of the contact reveals a thin, discontinuous basal conglomerate.

For deposition of unit 4 the stream moved farther to the northeast, but by then the gradient was very low and the stream sluggishly carried and deposited only clay and silt which collected in the channel and on the flood plain. Well-preserved carbonized leaves and stems are common in the silty shale of unit 4. The lines of alternating dots and dashes indicate the general configuration of the layering. Stage III of Figure C suggests very little erosion of unit 3 prior to deposition of unit 4.

When unit 5 was deposited, the stream appears to have reversed its direction of meandering and returned to the southwest where unit 5 is thickest. Unit 5 directly overlies unit 3 and is a non-silty shale probably representing accumulation of clay in quiet waters. Collection of non-silty clay in a stream channel seems contradictory because a stream channel is an environment of motion and clays should be carried in suspension rather than being deposited. Some channels, however, are filled with shale and the phenomenon may be explained by a stream being diverted from its accustomed course during time of flood and taking up a new channel. The abandoned channel is left as a standing body of water which gradually fills with clay or mud. The thick part of unit 5 is probably an abandoned channel. Stage IV of Figure C shows that erosion of parts of units 4 and 3 occurred before deposition of unit 5 began.

To appreciate how a stream changes position, a map view, instead of a cross-section must be examined. Figure D of Plate 2 is a hypothetical map showing the change of the stream's position from the time when unit 2 was laid down until the time of deposition of unit 5. The heavy line D-D' shows the location of the section along the road. The channel was relatively straight during deposition of unit 2 (large, widely spaced dots). When unit 3 was laid down (closely spaced dots) the channel began to meander and move toward A. The meander loop became much more developed during deposition of unit 4 (dashed pattern) and by time of unit 5 (no pattern) the loop was abandoned and the main channel was established southwest of the D-D' section.

The diversion of the stream removed the locality from the channel environment and changed it into a flood plain. Eventually a small peat swamp developed which is now represented by the thin coal seam located about 30 feet above road level. When the peat was forming the section looked like Stage IV of Figure C. Slowly the clay and peat of unit 5 gradually lost the water they contained and through time became compacted. The greatest compaction took place where unit 5 was thickest and thus a low spot was formed which became the focus of unit 6, another stream channel sandstone (Stage V of Figure C).

The sandstone of unit 6 marks the return of a stream whose course probably followed the depression resulting from clay compaction. Note that unit 6 has a typical trough-shaped channel cross-section that thickens downward. For sand to be deposited in the channel, the stream flow was more rapid than the stream of unit 4, suggesting the possibility of an increased or rejuvenated gradient. The layering of the sandstone dips gently to the southwest (toward D') indicating that the channel began in the northeast (toward D) and migrated toward D'.

After unit 6 had accumulated the stream gradient became steep enough for erosion to replace deposition. All units on the right (southwest) side of Figure B were eroded away to form a new valley in which the sandstone of unit 7 was deposited (Stage VI of Figure C). Unit 7 was then partly eroded to form the valley in which unit 8 accumulated.

The exposed section continues to the southwest toward Monessen but it is not described in this book. An interested person may follow for himself the further interplay of erosion and deposition. For example, unit 8 is cut out and replaced by another sandstone that may be labelled unit 9.

This exposure is along a high-speed, four-lane highway with insufficient area for parking. To properly view the section one may walk the railroad tracks located between the road and the river. It is not recommended that a large group visit this locality.

Stream channel deposits, cut-and-fill relationships, and erosional surfaces are common in Allegheny County and many can be seen when one knows what to look for. Some other stream channel deposits are located at Jacks Run between Bellevue and Pittsburgh (Locality 6), at the north end of Etna on Route 8 (Locality 14), and at Bauerstown (Locality 8).

Delta Environment

The delta is probably the most complex environment because it contains many of the environments already mentioned. The delta is a "halfway world" lying between land and sea. Streams build out a low, flat plain into the sea and a constant battle ensues between the sea attempting to wash the plain away and the stream fighting to enlarge it. The head or landward edge of a delta is marked by the beginning of distributary streams where the main channel separates downstream into many radially diverging subchannels. Figure 12 shows an ideally shaped ancient delta in northwestern Pennsylvania with distributary channels defining the extent of the delta. Distributary formation is the reverse of the situation that takes place farther upstream where tributary streams converge upon the main channel instead of diverging from it.

Some modern deltas, like those of the Mississippi and Nile, are very large. Both begin over 100 miles inland and fan out seaward so that the delta front, where land meets sea is more than 150 miles long. By comparison the two deltas shown on Figure 12 are small.

Many different sub-environments may exist on a delta. Distributary streams carve channels and deposit sandstone in the channels and siltstone and shale on the flood plains. Between distributary flood plains local swamps develop and form peat which is eventually altered to a thin coal

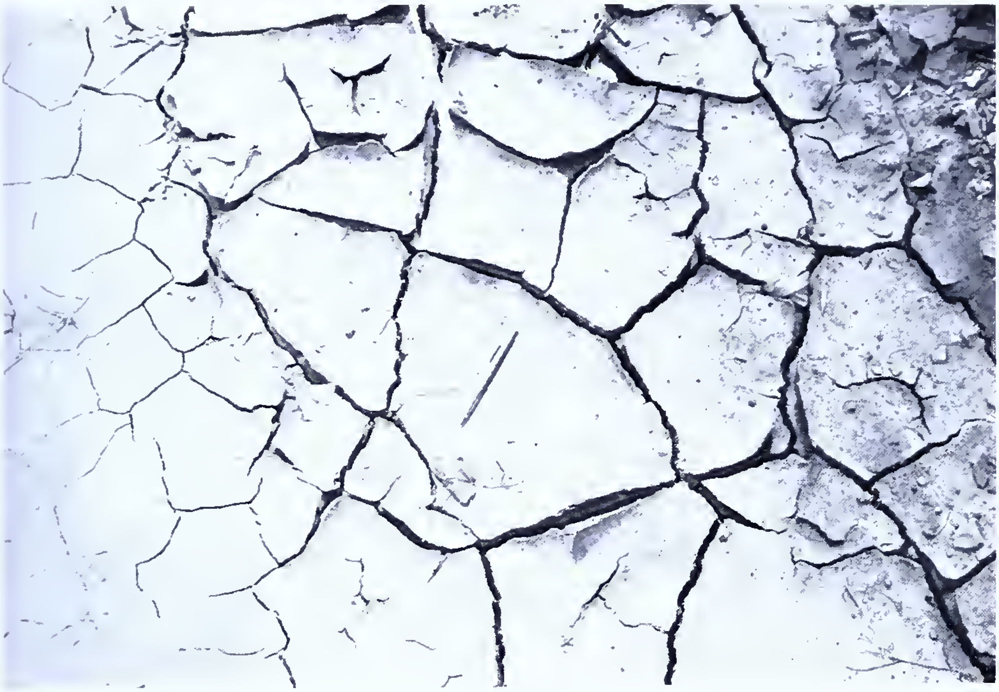
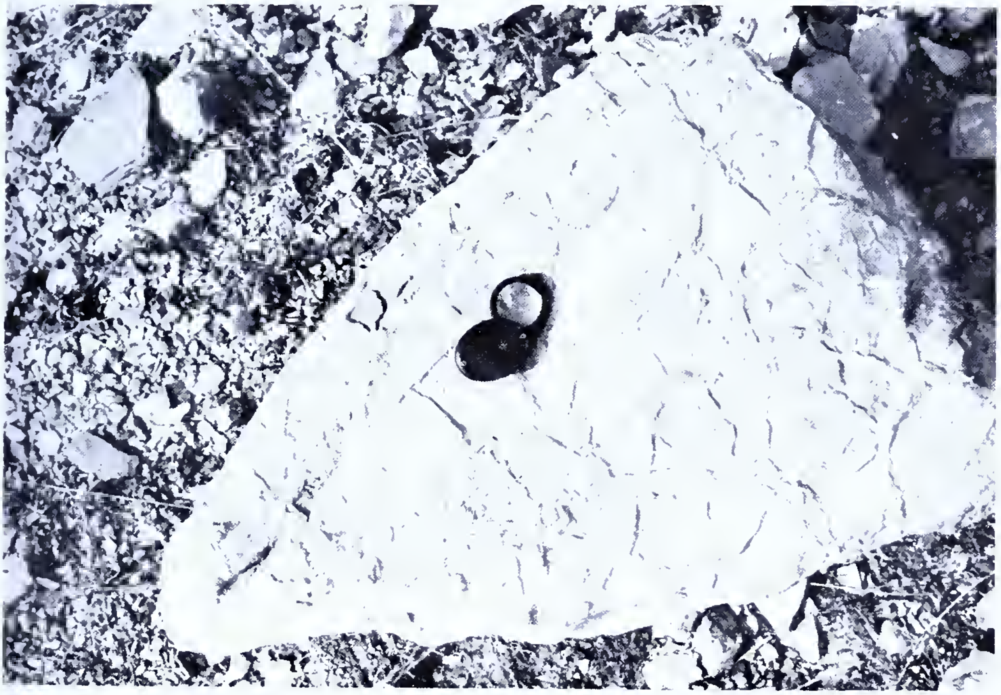


Figure 21. Modern sun cracks in dried mud.



igure 22. Fossil sun cracks in a carbonate mud rock from middle Casselman Formation (Locality 32—Kennywood Boulevard).

seam of limited areal extent. Small lakes can be present which may have given rise to some of the thin, local, discontinuous limestone layers in the county.

The size of the deltas varied considerably during the millions of years needed to deposit the sediments now exposed in Allegheny County. When a marine limestone such as the Ames was accumulating, Pittsburgh was underwater and no deltas existed at the limestone localities. During times of extensive coal formation and deposition of fresh water carbonates most of the scenery belonged to the swamp and lake environment and deltas played a minor part. But at times, deltas became very large and covered extensive areas at the expense of the lake, swamp, and open water environments.

The most prevalent and easily recognized rocks of the delta environment are interbedded reddish and greenish claystones and shales. These fine-grained rocks are exemplified by a layer called the "Pittsburgh Reds" which lies below the Ames limestone. The "Pittsburgh Reds" are exposed in the hillside across from the Jones and Laughlin Steel plant on the Parkway East (Locality 37), along Route 8 between Millvale and Etna (Locality 9), and at Brilliant Cut in Highland Park near the junction of Washington and Allegheny River Boulevard (Locality 38). Alternating flooding and drying on the delta plain oxidized the iron contained in the rock giving it a bright mottled red and green color. The claystones and shales of the Pittsburgh Reds contain carbonate cement and scattered carbonate nodules with marine fossils, indicating that the delta was at times flooded by marine waters of the open-water environment. At other times the shales and claystones were above water and exposed to the atmosphere as indicated by the presence of leaf and stem impressions, occasional footprints of amphibians and reptiles, impressions of rain drops, and sun cracks. Modern sun cracks in mud are shown in Figure 21; these may be compared to fossil sun cracks in a carbonate mud in deltaic rocks at Locality 32 near Kennywood (Figure 22).

Siltstones, shales, and claystones with a gray or brown color are also common rocks of the delta environment, but they are also abundant in the open water, lake, and flood plain environments. Determining the specific environment of these rocks is often difficult, even for a geologist.

IV STRATIGRAPHY

by

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Pennsylvania Geological Survey

INTRODUCTION

Stratigraphy deals with the order, arrangement, age, and naming of sedimentary rocks. To gain perspective on the stratigraphy of the rocks of Pittsburgh let us first look at the overall world picture and then place Pittsburgh into that broad framework.

Earth history is divided into large divisions of time called eras (Figure 23). The oldest rocks, those more than one-half billion years old, are assigned to the Archeozoic Era and the Proterozoic Era. Because these rocks are mainly igneous and metamorphic rocks, they are not discussed in this book except to say that they are the base or "basement" upon which the younger sedimentary rocks have accumulated. The basement lies below Pittsburgh at an estimated depth of 16,000 feet. The younger rocks that rest on the basement throughout the world were deposited during the last half billion years of earth history, and this relatively short time is divided into three eras, the oldest called the Paleozoic, the middle the Mesozoic Era, and the youngest Cenozoic Era.

The rocks of western Pennsylvania were formed during the Paleozoic Era. This era is split into seven time subdivisions called Periods which, in order from oldest to youngest are: Cambrian, Ordovician, Silurian, Devonian, Mississippian, Pennsylvanian, and Permian (see Figure 23). The next to youngest period, the Pennsylvanian, is named for the time when the rocks now at the surface in the western part of the State were being deposited. The rocks that are actually deposited during a period of time are referred to as a System. Thus the rocks of the Permian Period are the Permian System, and those of the Pennsylvanian Period are the Pennsylvanian System. All the Systems of the Paleozoic Era are represented in the rocks of Pittsburgh, but most are far below ground surface. Only 1,100 to 1,200 feet of Pennsylvanian and Permian rocks are exposed at the surface. The rest of the almost 16,000 feet of Paleozoic age rock is beneath us and can be reached only by drilling. Figure 24 shows the sequence and age of the rocks that would be encountered if a hole were drilled from the surface to basement at Pittsburgh.

This chapter delves only into the subdivisions of the surface rocks, however the subsurface rocks have also been catalogued and described in greater detail than is shown by Figure 24.

SURFACE ROCKS OF ALLEGHENY COUNTY

Figure 25 represents the column of rocks exposed in the county. The three columns on the right (columns 4, 5, and 6) are discussed here and the three on the left (columns 1, 2, and 3) are treated in the following heading.

Column 5 headed "Generalized Geologic Section" shows the rocks of the county as if they were all present in one long exposure 1,100-1,200

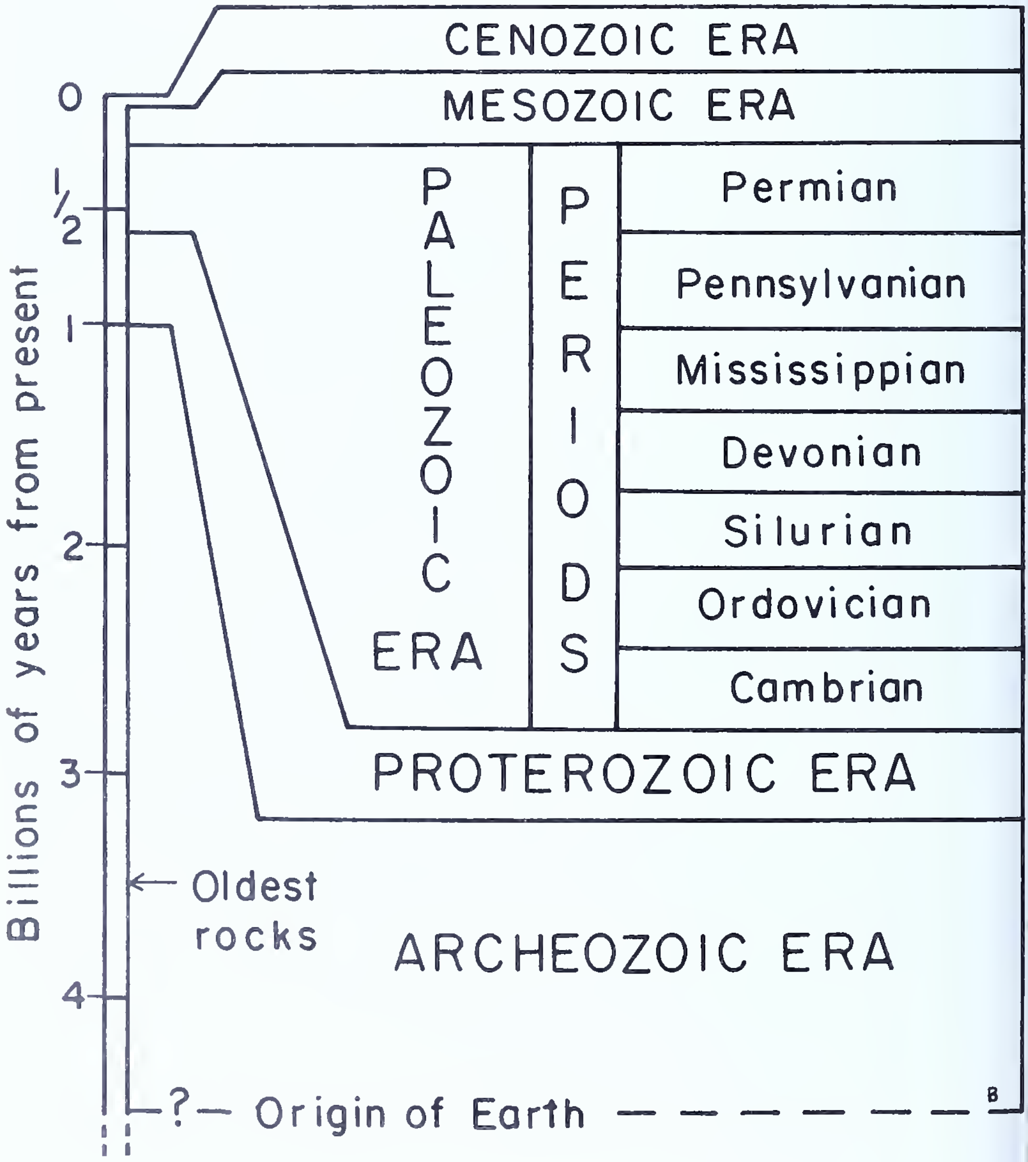


Figure 23. Eras of geologic time and periods of the Paleozoic Era.

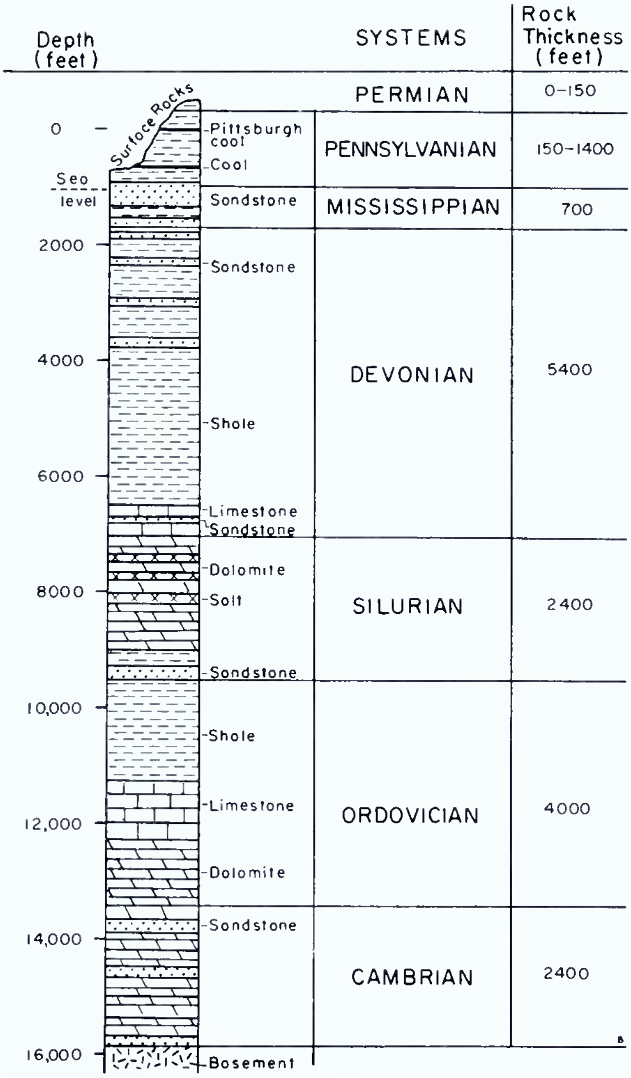


Figure 24. Subsurface rocks below Pittsburgh.

feet high. As such an exposure does not exist, the column is a composite prepared by piecing together much shorter sections that are exposed within the county.

The generalized geologic section has two purposes. First, it shows the order of succession of rock types and second, it indicates the interval of separation between individual rock units. Column 6 identifies by name some of the individual beds and column 4 shows the interval in feet between the individual beds.

A distinctive feature of the geologic section is that the rock succession is repetitious. Coal seams and limestone beds recur throughout the whole section, red siltstones, shales and claystones abbreviated as "red beds" are intermittently present in the lower half, and sandstones and shales are common everywhere. Because of this repetitious nature, one cannot immediately locate an isolated outcrop in its proper position in the geologic section. The problem is further complicated because one sandstone or coal may look very much like other sandstones or coals. How then, can one know where an outcrop fits into the general section? One aid is to know how far above or below a well-known recognizable marker bed the outcrop is located. These marker beds are the Benwood carbonate layer, the Pittsburgh coal, the Ames limestone, and the Upper Freeport coal. The marker beds are widespread throughout the county and are the most readily recognized units, the Benwood being the thickest carbonate rock, the Pittsburgh and Upper Freeport coals the thickest coals, and the Ames, the most fossiliferous limestone.

Across the Monongahela River from downtown Pittsburgh, the rocks of Mt. Washington are exposed at the portal of the Fort Pitt tunnel (Locality 36). One of the most conspicuous layers is a cross-bedded sandstone about halfway up the hill. This sandstone can be identified by relating its position to the marker beds, the Pittsburgh coal and the Ames limestone. The Pittsburgh coal lies near the top of the hill about at the level of the trees and the Ames is near the base of the hill. Comparing the hillside with the geologic section, the sandstone halfway up the hill lies halfway between the Pittsburgh coal and the Ames, and the sandstone lying between these marker beds on the geologic section is the Morgantown sandstone.

Suppose you are collecting fossils from the Ames limestone on Route 22 between Monroeville and Murrysville (Locality 42) and you also wish to collect from the Woods Run limestone. The geologic section indicates that the Woods Run lies about 100 feet below the Ames. If you have the 7½ minute Murrysville topographic map at your disposal you can determine that the elevation of the Ames outcrop is about 1,020 feet. The Woods Run limestone then should be located at approximately 920 feet. The 920 foot contour crosses Route 22 about one mile down the road at the overpass of Route 286 where the Woods Run is an impure limestone less than six inches thick located at the junction (Locality 43).

Additional comments are necessary because the geologic section is generalized. A generalized section means that each unit has an average thickness and that the intervals between units are also averages. Therefore, changes in thickness are not shown. The Morgantown sandstone, for example, ranges from less than 15 feet to about 75 feet thick and its base may range from 170 to 210 feet below the Pittsburgh coal. In the geologic section, however, the Morgantown, like all the other units, is exhibited as a horizontal bed of constant thickness whereas in reality the Morgantown is, at least in part, a channel sandstone and its base shows cut and fill and not a horizontal contact.

On the geologic section the marker beds extend across the width of the column but the other units change from one rock type to another, usually from sandstone to shale or from limestone to shale. These changes of rock type mean that a given rock type is not always found at a specific interval from a marker bed. For example, the Pine Creek limestone is absent in some parts of the county. Its place, about 160 feet below the Ames, may be taken by a sandstone. The geologic section does not indicate whether the change of rock type occurs by cut and fill or by transition from one rock type to another.

NAMING OF SURFACE ROCKS

The geologic details inherent in thousands of feet of rock deposited during a period of geologic time are much too great to be understood when examined as a single unit. So geologists divide the rocks into segments of more workable dimension called formations and groups. The formations and groups of the Pennsylvanian and Permian Systems in Allegheny County are shown in columns 1, 2, and 3 of Figure 25. These groups are separated mainly on the basis of minable versus nonminable coal seams.

The lowest and oldest exposed group is the Allegheny Group, with the minable Upper Freeport coal at the top. Only the upper 100 feet of the Allegheny is exposed at the surface, the rest of the group being in subsurface. A subdivision of the Allegheny Group is the Freeport Formation whose upper boundary, like the Allegheny Group, is the top of the Upper Freeport coal.

The Conemaugh Group is the thickest sequence, being over 600 feet thick. Practically no minable coal seams occur in the group and its boundaries extend from the top of the Upper Freeport coal up to the base of the Pittsburgh coal. Two formations, a lower Glenshaw Formation and an upper Casselman Formation, each about 300 feet thick, divide the Conemaugh approximately in half. The boundary between the two formations is the top of the Ames limestone (Flint, 1965).

The uppermost and youngest group of the Pennsylvanian System is the Monongahela Group. It is about 300 feet thick and includes all the rocks from the base of the Pittsburgh coal to the base of the Waynesburg coal. The two unequally thick divisions of the group are the Pittsburgh and Uniontown Formations.

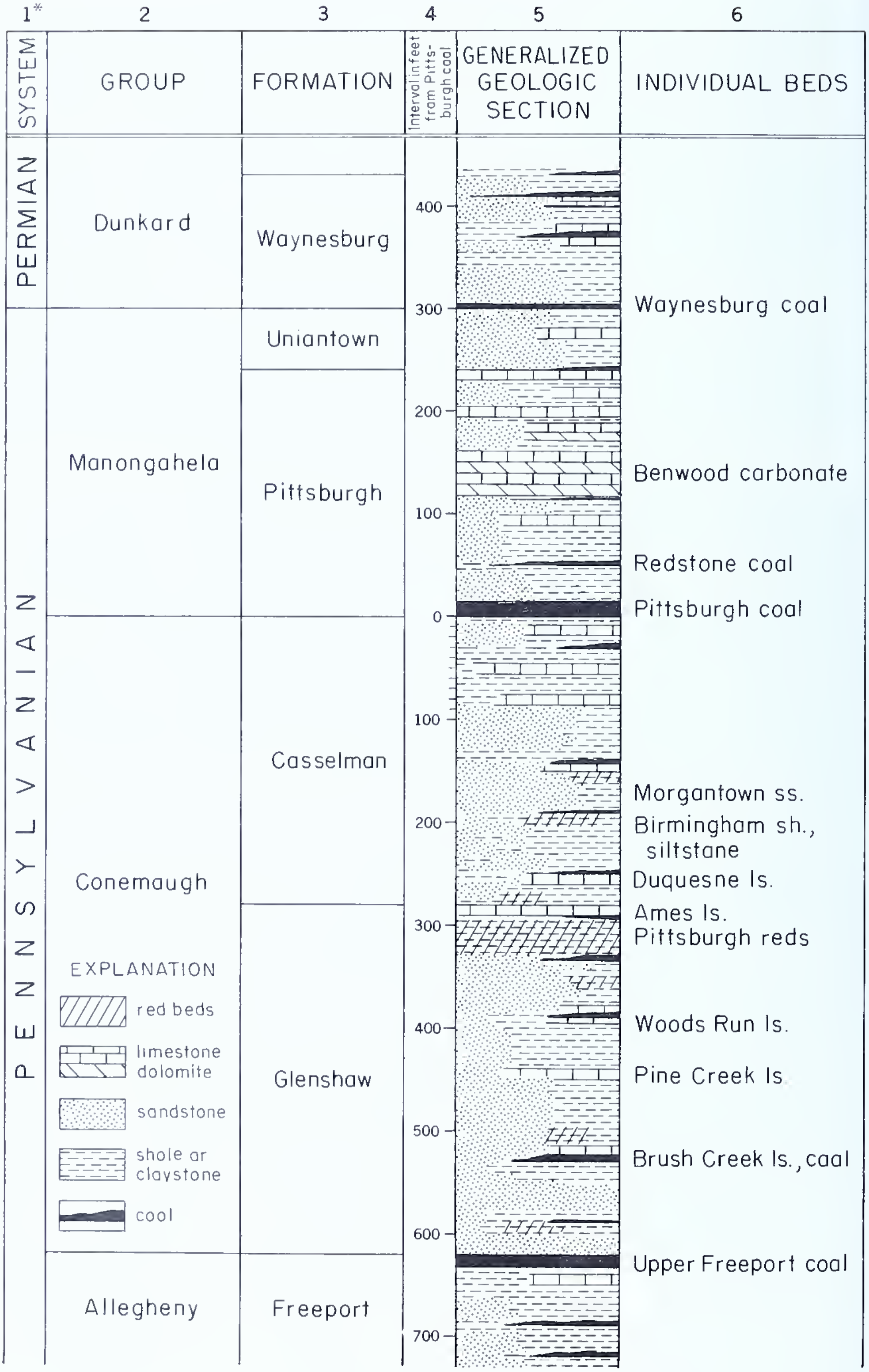


Figure 25. Generalized columnar section of the exposed rocks in Allegheny County.

*Column numbers referred to in text.

The youngest 150 feet of rock within the county belong to the Waynesburg Formation of the Dunkard Group. Traditionally, the Dunkard has been assigned to the Permian System, but plant fossils in the Waynesburg Formation have features which are characteristic of both Pennsylvanian and Permian age fossils from other parts of the world. Some authorities now consider the Waynesburg Formation to be a transition between true Pennsylvanian age rocks and true Permian age rocks (Berryhill and Swanson, 1962).

DISTRIBUTION OF FORMATIONS AND GROUPS

The groups and formations of the surface rocks are not scattered haphazardly around the county; they are arranged in a definite order and this order is shown on the geologic map of Allegheny County (Plate 1, Figure B). The four patterns on the map designate where the four groups, Allegheny, Conemaugh, Monongahela, and Dunkard are located at the surface. The rocks themselves, however, may not be well exposed because of cover by soil, buildings, and roads. Usually the rocks can be seen only on steep slopes and man-made exposures such as highway cuts.

The map shows that the Allegheny Group is exposed only at three places in the northern part of the county, all of them being stream valleys. Along the Allegheny River from Tarentum to Freeport is the largest area of exposure. The Freeport Formation was named for the rocks that crop out in the vicinity of the town.

In short exposures the rocks of the Pittsburgh area commonly appear as horizontal layers, but if a long enough outcrop of a mile or more in length were available, one could see that the layers, instead of being perfectly flat, actually dip or tilt in various directions. Many of the reasons for the dips are discussed in Section V, Structural Geology. One of these directions is a regional dip to the south or southwest at an average rate of 30 to 35 feet per mile. Because of the gentle dip, the Allegheny Group in northern Allegheny County lies below the surface in the southern part of the county and underlies the Conemaugh, Monongahela and Dunkard Groups. Therefore, the Upper Freeport coal, instead of cropping out as it does around Tarentum and Allison Park, lies at a depth of approximately 900 feet near the Allegheny-Washington County border.

The Conemaugh Group covers almost all of the northern half of the county and in the southern half it is exposed in the valleys of the Monongahela and Youghiogheny Rivers and Chartiers and Peters Creeks. On the geologic map the base of the Conemaugh is represented by the line separating the Allegheny from the Conemaugh Group; this line is the outcrop of the Upper Freeport coal. The much more extensive outcrop is the Pittsburgh coal which occurs at the contact between the top of the Conemaugh and the base of the Monongahela Group. On account of the regional dip, the Glenshaw Formation, the lower division of the Conemaugh, is well-exposed north of the Allegheny and Ohio Rivers whereas the Casselman Formation, the upper half of the Conemaugh, is best seen south of the two rivers.

The Monongahela Group lies almost entirely south of the Allegheny and Ohio Rivers, occupying most of the southern half of the county. Its irregular outcrop pattern is the result of stream erosion cutting deep valleys completely through the group and into the underlying Conemaugh. A few erosional remnants of the Monongahela Group remain on the tops of some high hills in the northern part of the county, giving evidence that at one time, before the present amount of erosion had taken place, the Monongahela Group extended well north of the present boundaries and probably covered all of Allegheny County.

The Dunkard Group, containing the youngest rocks of the county, is similar to the Monongahela Group of northern Allegheny County in that both are erosional remnants capping hilltops. The Dunkard, however, is located only in southern Allegheny County. Its contact with the underlying Monongahela Group is shown by the outcrop pattern of the Waynesburg coal.

The geologic map offers another aid in placing an unknown outcrop in its proper position in the geologic section. In the southern half of the county an outcrop can belong only to the Dunkard, Monongahela, or Casselman Formation of the Conemaugh Group whereas in the northern half the Glenshaw Formation and Allegheny Group are the exposed units. The starting point for identifying an outcrop is to know in what group the outcrop occurs and this is determined by placing the geographic location of the outcrop on the geologic map. The next step is to apply the marker-bed-interval method discussed under the previous heading "Surface Rocks of Allegheny County".

DEPOSITIONAL ENVIRONMENTS OF GROUPS AND FORMATIONS IN ALLEGHENY COUNTY

Allegheny Group

The Freeport Formation of the Allegheny Group is exposed in the valley of Bull Creek from Tarentum to the road junction 3.1 miles north, where McDowell Run enters Bull Creek. The Upper Freeport coal, four feet thick, crops out in a cliff behind some homes at this junction (Locality 17).

Along Route 8 for two miles south of Allison Park, the Freeport Formation, with the Upper Freeport coal at the top can be seen in the stream valley and in the road cuts. Underneath the coal in descending order are a claystone, a limestone, and another claystone. The claystone and limestone represent deposition in a lake environment and the coal is from a swamp environment. The Freeport Formation here, therefore, shows a change upward from a lake environment into that of a swamp.

Changes occur not only vertically, but also horizontally. At the parking lot of the J. & L. Warehouse 1.4 mile south of Allison Park on Route 8 the claystone and limestone of the lake environment can be seen (Figure 26, Locality 11), and one-fourth mile farther south, in the hillside between the diner and Alberts store, sandstone and shale, probably of stream origin, replace the claystone and limestone (Figure 27, Locality 12).

Conemaugh Group

The characteristics of the Conemaugh Group are the occurrence of red beds, the presence of thin marine limestone, the lack of minable coal

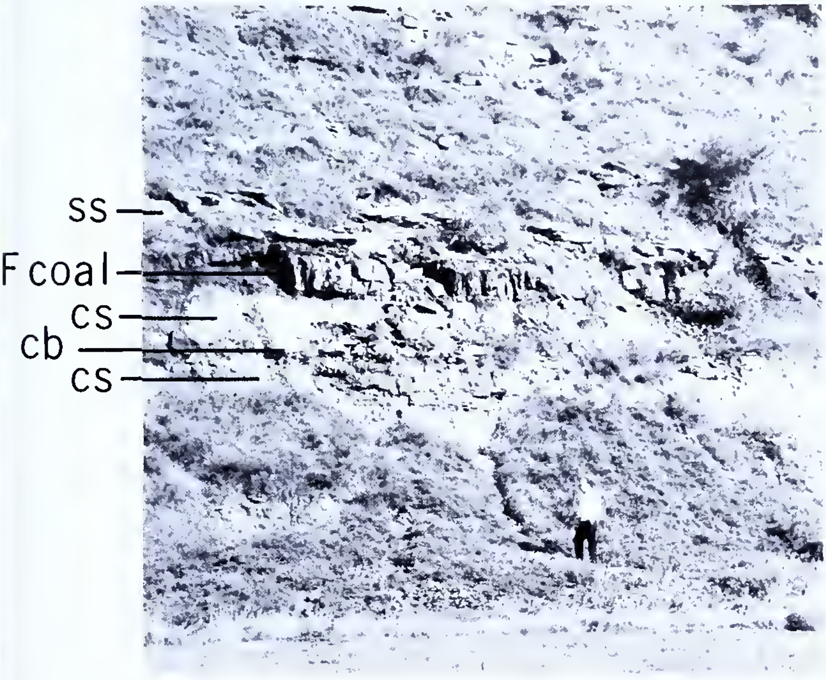


Figure 26. Rocks representing lake and swamp environments of the Allegheny Group (Locality 11—Jones and Laughlin Warehouse, Route 8). Symbols: ss—sandstone, UF coal—Upper Freeport coal, cs—claystone, cb—carbonate rock.

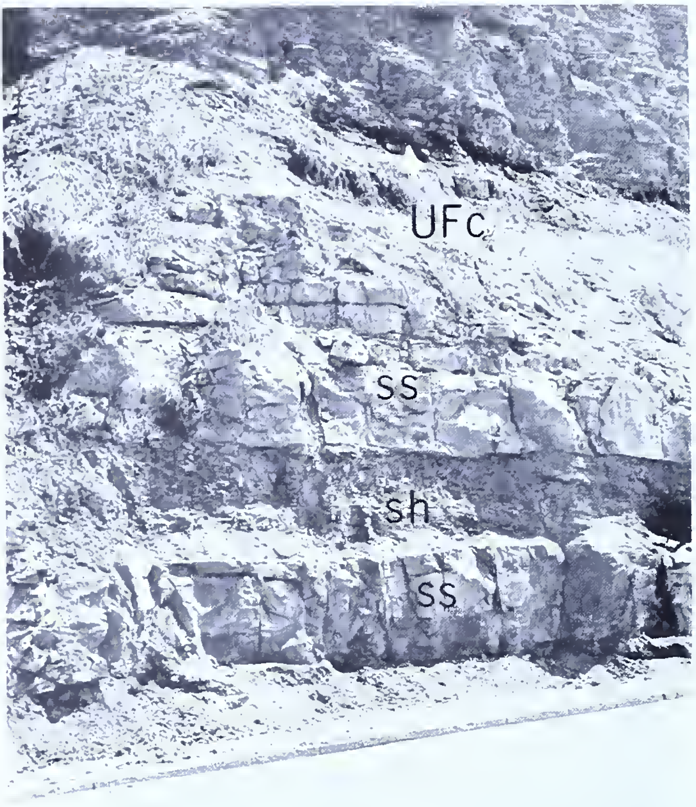


Figure 27. Lake environment of Figure 26 replaced by sandstone (ss) and shale (sh) of stream environment. (Locality 12—Route 8 between diner and Alberts store). UFc—Upper Freeport coal.

seams, and a greater abundance of thick sandstone units most of which are channel sandstones.

The Glenshaw Formation was named for the rocks exposed around Glenshaw, particularly along Pine Creek and Route 8 from Glenshaw to Etna (Flint, 1965). This area is the "type locality" of the Glenshaw Formation. The fossiliferous Pine Creek open-water limestone is exposed just above head level at the bend in Route 8 at the north edge of Etna (Figure 28, Locality 13). Above the limestone are shales and sandstones deposited in a flood plain and channel environment. The sandstone with its cut-and-fill relations to the shale is well exposed at the north end of the Etna bypass (Locality 14, Figure 29). Below the Pine Creek limestone at Locality 13 is a fossiliferous shale and siltstone of marine origin which grades into sandstone less than 500 feet to the north. This change of rock type is not by cut and fill but by transition and so the sandstone was also deposited in an open-water environment. Fossils are plentiful at this locality but the heavy traffic makes collecting very dangerous for large groups.

The Glenshaw Formation, the lower half of the Conemaugh Group, has more rocks of the open-water environment than does the Casselman Formation, the upper half of the group. Other localities where the open-

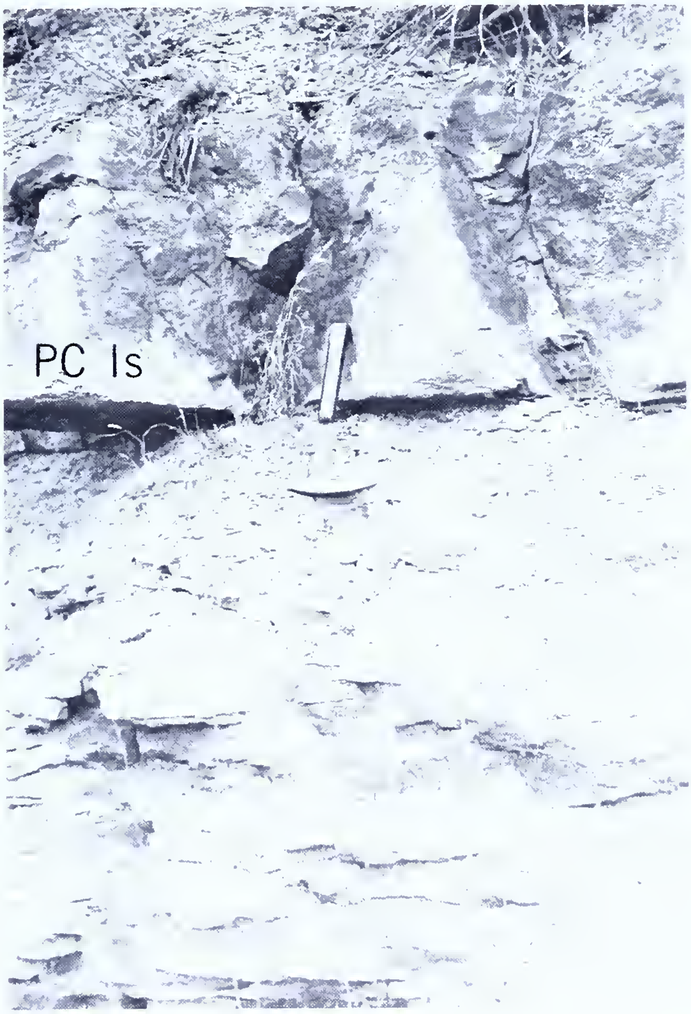


Figure 28. Fossiliferous Pine Creek limestone (PC ls) and underlying open-water shale and siltstone. (Locality 13—Route 8 at north edge of Etna).

water rocks can be observed are above the Upper Freeport coal at Allison Park railroad station (Locality 10), the Brush Creek limestone at the south end of the Sewickley bridge (Locality 4), and the interval from the Pine Creek to the Brush Creek limestone along Route 22 just west of Murrysville (Locality 44).

Channel sandstones also occur in the Glenshaw Formation. Where Jack's Run enters the Ohio River at the boundary of Bellevue and Pittsburgh, the sandstone below the Brush Creek limestone is well exposed in the cliff along the Penn-Central railroad tracks (Locality 6A, Figure 30). The sandstone cuts out the underlying dark shale and also shows well-developed cross bedding about 900 feet southeast of Jack's Run valley. Sandstones of probable channel origin are also located at Stoop's Ferry along Route 51 (Locality 3) and in the cliff at Natrona (Locality 18).

Red beds, although recurring throughout the Conemaugh, tend to be concentrated in the upper part of the Glenshaw and lower half of the Casselman Formation; they may be readily seen along the Allegheny River cliffs from downtown Pittsburgh to New Kensington. Red beds are believed to indicate deposition on the plain of a delta.

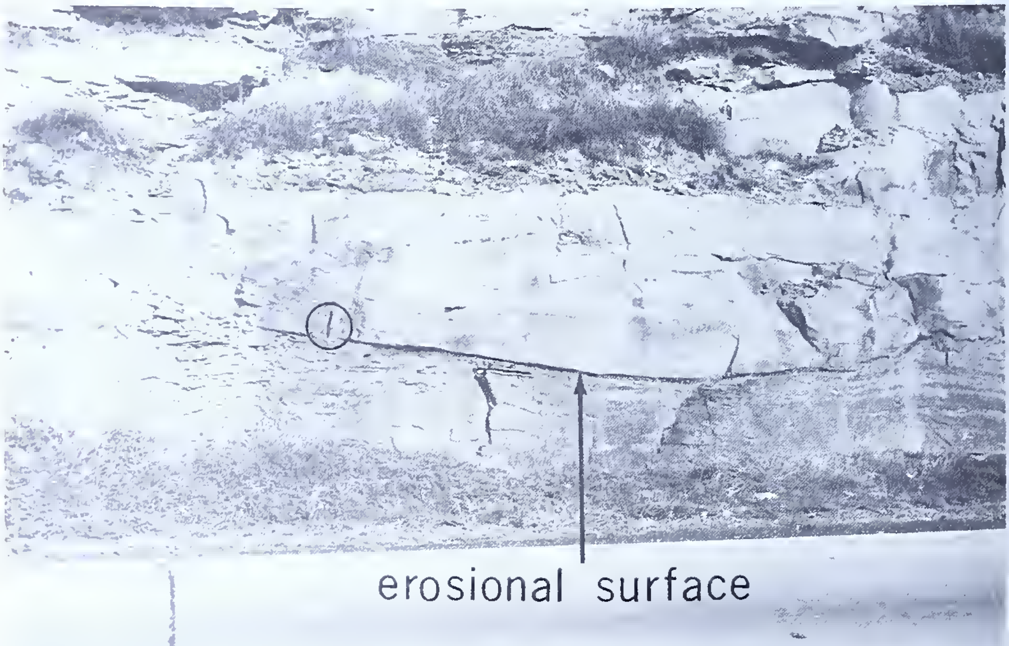


Figure 29. A middle Glenshaw channel sandstone showing cut-and-fill relation with underlying shale (Locality 14—north end of Etna bypass). Circle shows hammer for scale.

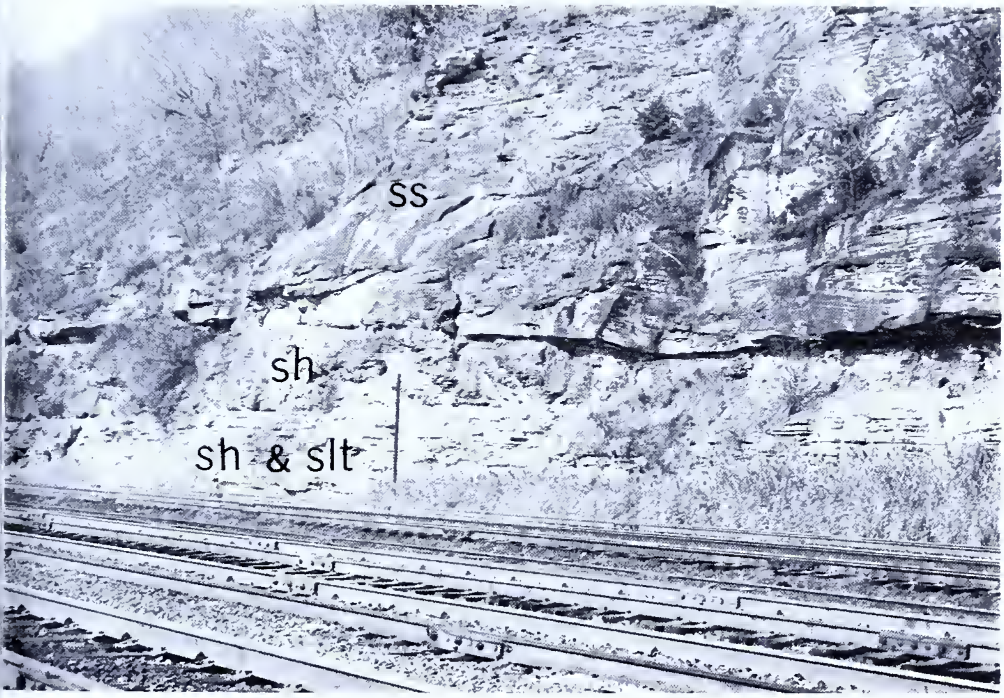


Figure 30. A lower Glenshaw channel sandstone (ss) cuts out underlying shale (sh). Locality 6A—Penn-Central Railroad, Jacks Run and Ohio River.)

Brilliant Cut (Locality 38) near the junction of Allegheny River and Washington Boulevard shows the vertical change of rock type in the middle part of the Conemaugh. In a University of Pittsburgh masters thesis, William Tindell divided the cliff into 23 units with each unit having a specific rock type. Table 1 is adapted from Tindell's work; columns "1" and "2" showing the unit numbers and the rock types and columns "3" and "4" showing the thickness of the units and the inferred environments of deposition. Figure 31 is a sketch of Brilliant Cut with units 6, 11 (Ames limestone), and 18 marked for easy identification.

In the almost 170 feet of rock exposed at Brilliant Cut, the rock types and the inferred environments repeat themselves several times. This recurrence of similar rock types is so striking in eastern and midcontinental United States that a special term "cyclothem" has been applied to the phenomenon. For example, note that units 6, 20, and 23 are sandy; units 8, 15, and 22 are thin gray claystones and that the thickest units develop in the delta environment. Subdivision of the Pennsylvanian rocks into cyclothems has been attempted by some geologists using cyclothems as a basis, but one cannot predict from any given cyclothem what rock types the preceding and succeeding cyclothems will have.

Other sections in the middle Conemaugh may be seen along Kennywood Boulevard between Rankin Bridge and Kennywood (Locality 32) and along the east side of the Monongahela River from Glassport to Belle Bridge (Locality 34). Both sections show the interval from the Morgantown sandstone to below the Ames limestone. On McKnight Road between Babcock Boulevard and McIntyre Road, coal and red beds above and below the Ames are exposed (Locality 7).

The upper 200 feet of the Casselman Formation from the Morgantown sandstone up to the base of the Pittsburgh coal are exposed in Pittsburgh

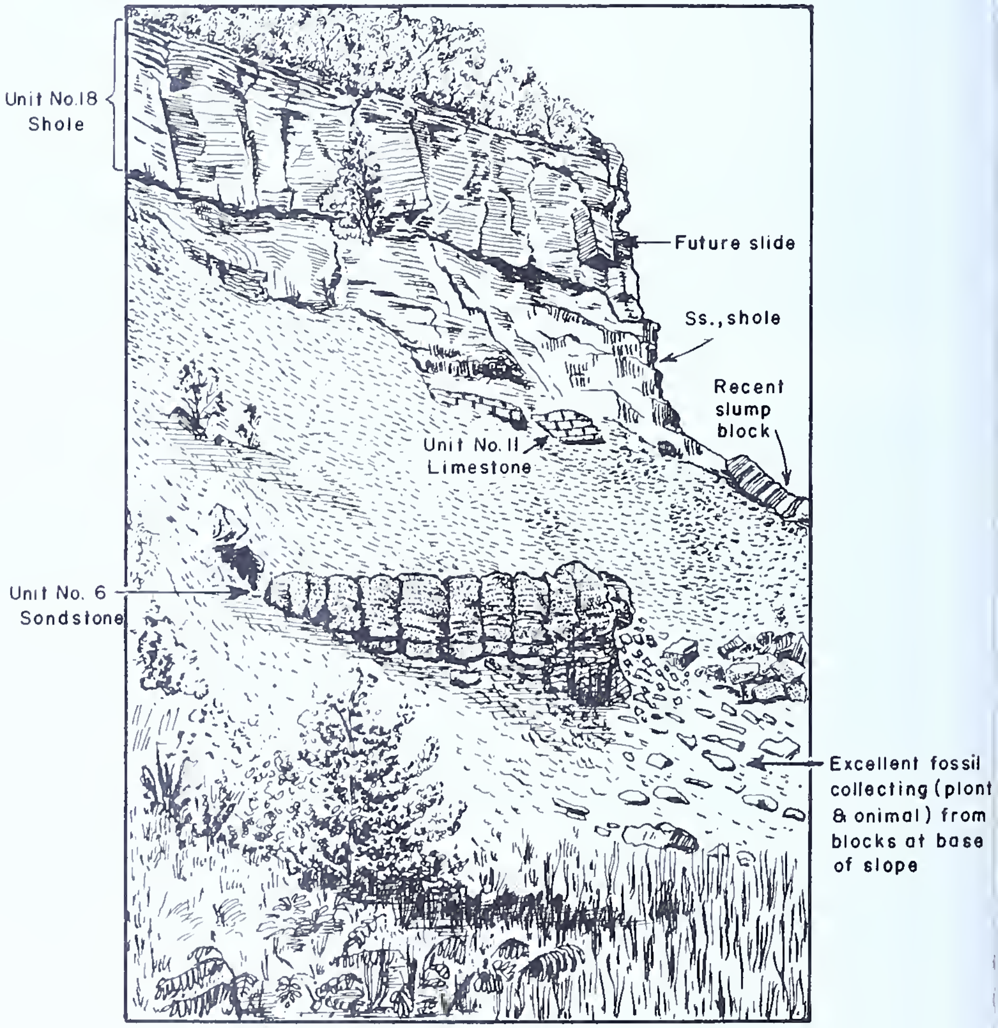


Figure 31. Brilliant Cut (Locality 38). Location is shown of units 6, 11 (Ames limestone), and 18 (Birmingham shale) of Table 1. Jointing in unit 18 contributes to landslides. Note the recent slump block with its layering dipping into the cliff. For explanation see Section V, Structural Geology.

Table 1. *Rock Types and Environments at Brilliant Cut (Adapted from Tindell, 1950)*

1 *Unit No.*	*2* *Rock Type*	*3* *Thickness*	*4* *Environment*
23	Sandstone, gray, cross bedded (Morgantown)		Stream
22	Gray claystone	1′ - 7″	Lake
21	Red claystone with limestone nodules	14′ - 11″	Delta?
20	Sandy shale, gray-green	3′ - 9″	Stream
19	Red shale, limestone nodules	6′ - 4″	Delta?
18	Shale, gray-green, plant fossils	45′ - 0″	
17	Black shale, laminated, plant fossils	5′ - 6″	Lake? Swamp?
16	Yellowish claystone	0′ - ½″	Lake
15	Gray claystone	2′ - 3″	
14	Red claystone, limestone nodules	10′ - 10″	Delta
13	Gray-green shale	4′ - 2″	Stream (Flood plain)
12	Red, gray-green shale with limestone nodules	17′ - 3″	Delta
11	Ames limestone	3′ - 4″	Open water
10	Coal	0′ - 6″	Swamp
9	Blue-gray claystone	0′ - ½″	Lake
8	Gray claystone	3′ - 4″	
7	Red, olive claystone, limestone nodules	23′ - 2″	Delta
6	Sandstone and sandy shale	17′ - 3″	Stream
5	Limestone lenses, red shale	3′ - 6″	Delta?
4	Gray-green shale, clam shells	2′ - 0″	Open water
3	Black shale	1′ - 10″	Open water

and in the southern half of the county. Good sections are located on Banksville Road from the Morgantown sandstone at the Parkway West entrance to the Pittsburgh coal at Wenzell Avenue, a distance of 1.5 miles (Locality 24). The interval from the Pittsburgh coal to about the top of the Morgantown may be seen in roadcuts and hillside cuts behind stores on Route 51 from Southland Shopping Center to Large. Approximately 1.2 miles north of Large, (Locality 30) a channel sandstone, lying between the Pittsburgh coal and the Morgantown, thickens from a few feet to more than 20 feet and then becomes thin again on the other side of the channel.

Channel sandstones are most abundant from about 100 to 200 feet below the Pittsburgh coal whereas in the upper 100 feet of the Casselman the sandstones are much diminished and are replaced by thin fresh-water carbonate layers. Figure 32 shows a thin fresh-water carbonate rock on

Route 51. Good outcrops of carbonate rock also occur below the Pittsburgh coal on West Liberty Avenue between Capital Avenue and the overhead railroad trestle near the south end of the Liberty Tunnels (Locality 26).

A fine outcrop for large group study is in the park at the end of 21st Street on the South Side (Locality 25). At the top of the cliff is a channel sandstone which can be examined in three dimensions by walking to the athletic field located on the upper level of the park. Below the sandstone in the cliff is an eight-foot sequence which consists of coal, fresh-water carbonate rock, silty shale, and another coal. Underneath

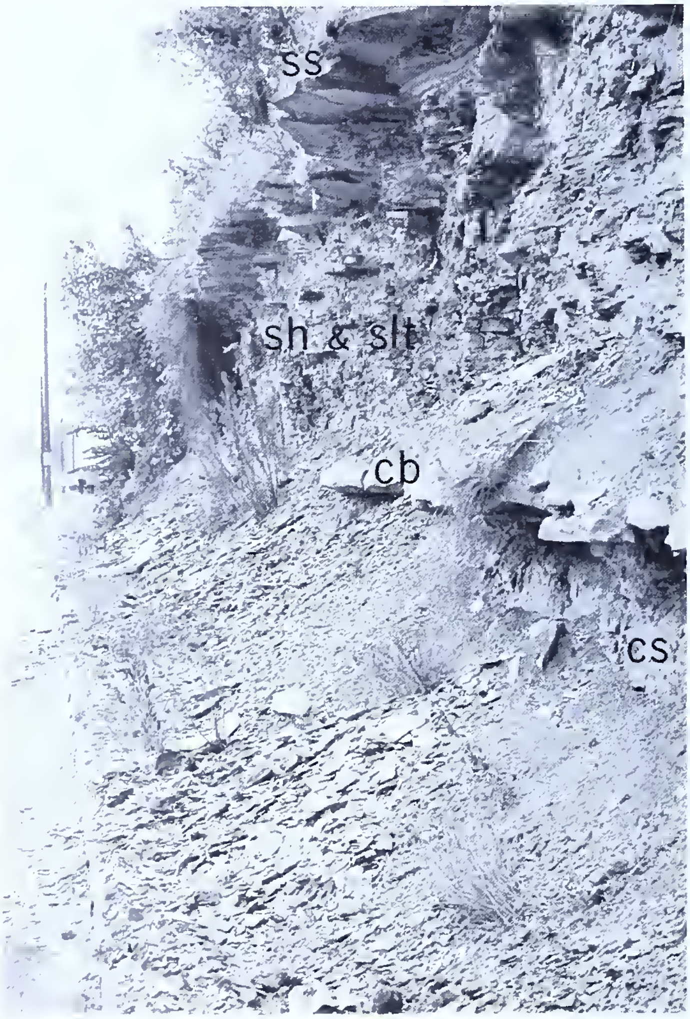


Figure 32. Thin, fresh-water carbonate rock (cb) in upper Casselman Formation. (Route 51, south of Southland Shopping Center). Symbols: ss—sandstone, sh—shale, slt—siltstone, cs—claystone.

this is a poorly exposed 10 to 15 feet of red, green, and gray claystone. At the base of the cliff is cross-bedded Morgantown sandstone.

Monongahela Group

The Monongahela Group is characterized by an abundance of fresh-water carbonate rocks, few red beds, and a relative lack of sandstone. Thick sandstones that are dominant in the Conemaugh are replaced by thin sandstones in the Monongahela. The main rock types besides carbonate are shale and siltstone.

The Pittsburgh Formation, which makes up more than three-fourths of the Monongahela Group contains in the lower part, two minable coals, the Pittsburgh and Redstone seams; the upper half is dominated by fresh-water carbonate rock. A sequence of carbonate layers mostly of dolomite composition and about 40 feet thick is called the Benwood "limestone" or carbonate. The base of this carbonate sequence is easily recognized and is valuable as a marker bed.

The carbonate rocks of the Monongahela Group were deposited in a lake environment. If these carbonates are followed south into West Virginia they change into sandstones and red beds and begin to look similar to the Conemaugh rocks of Allegheny County. Geologists interpret this change of rock type as a change from a lake environment in Pennsylvania to a deltaic environment in West Virginia. This is a transition that takes place horizontally; change in cyclothemic deposition occurs vertically (Arkle, 1959).

Excellent roadcuts in the Monongahela Group occur on Interstate Route 79 from Heidelberg south past Bridgeville. Two spectacular cuts, one at Heidelberg (Locality 21) and the other at the Bridgeville exit (Locality 20, Figure 33), expose the interval from above the Benwood down almost to the Pittsburgh coal. Along Route 51 from the junction of Route 88 to the top of the hill at Brownsville Road, the whole group is present. Particularly well exposed is the Pittsburgh coal (Locality 27) and also the base of the Benwood behind Rollins Furniture store (Locality 28). The basal Benwood may also be observed along old Route 51 at Option, where large blocks of Benwood have fallen because of being undercut by differential erosion (Locality 29, Figure 34). Intermittent exposures occur along Painters Run Road from the Pittsburgh coal at Bower Hill Road (Locality 22, Figure 36) to the Benwood on Route 19 (Locality 23, Figure 9).

Dunkard Group

The Dunkard Group is poorly exposed in the county because it occupies hilltops rather than valleys. The group is drab in color, contains several thin, impure coals, patchy fresh-water carbonate rocks, and the

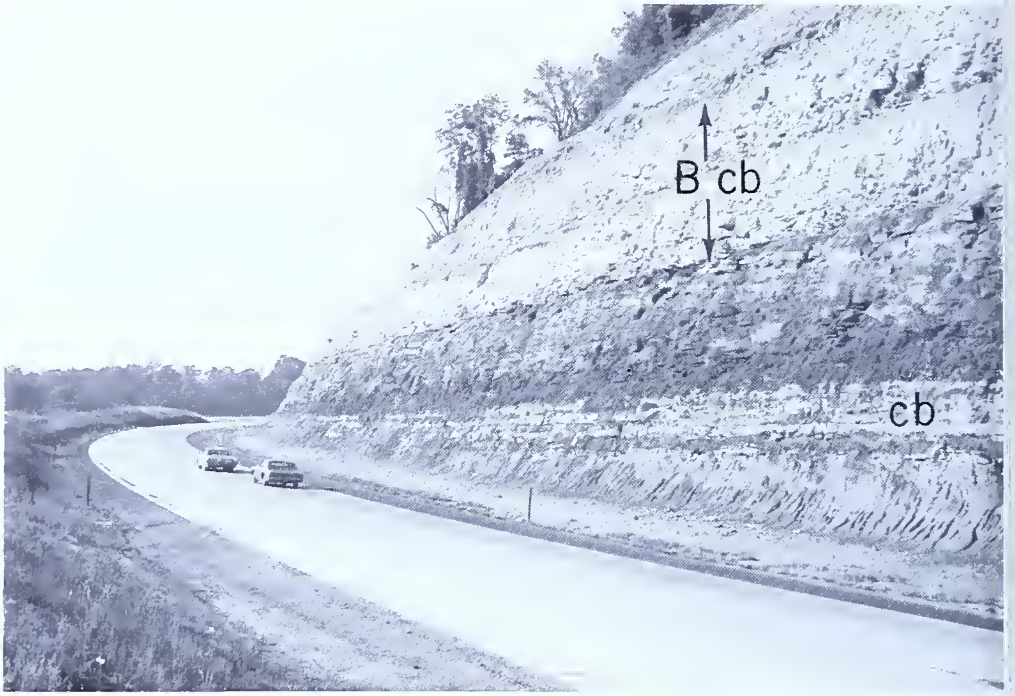


Figure 33. Lower part of Pittsburgh Formation. (Locality 20—Bridgeville Interchange, Interstate Route 79). Symbols: Bcb—Benwood carbonate layer, cb—fresh-water carbonate layer.

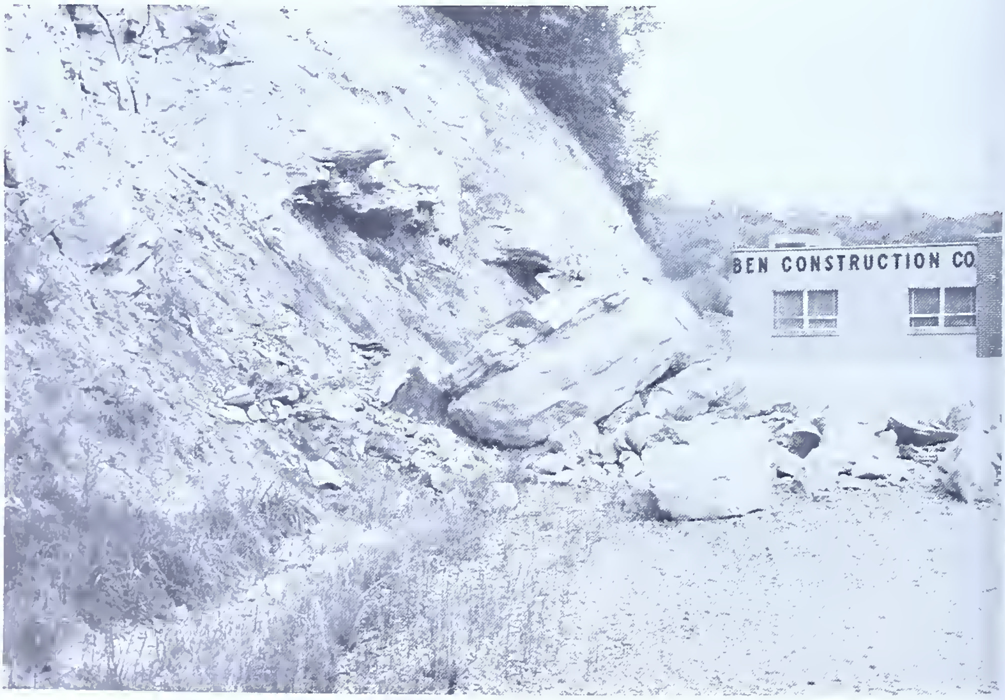


Figure 34. Rockfalls in basal Benwood carbonate layer caused by weathering of underlying shale. (Locality 29—old Route 51 at Option).

main rock type is siltstone and shale. In many respects it appears similar to the Monongahela Group, but lacks the abundant carbonate units. Dunkard outcrops may be examined on Route 88 between Bethel Church Road and South Park (Locality 31), around the South Hills Village shopping center, near the Allegheny-Westmoreland County line on Route 51, and between Bridgeville and Canonsburg on Interstate 79 in Washington County (see Figure 5).

CYCLOTHEMS, FACIES, AND HIATUSES

The concept of cyclothems was born from the observation that certain rock types, especially coal, repeat themselves in a vague, yet systematic vertical sequence. A corollary to this concept is that certain depositional environments are also repetitious. The simple consequence of these ideas is that in any given geographic spot different environments have existed at different times. At Brilliant Cut, for example, the rocks exposed probably represent an accumulation of over 2 million years duration and throughout that time, environments appeared only to disappear and be replaced by other environments.

Rocks change horizontally as well as vertically. Where an ancient swamp ended the coal deposited in it becomes thin and disappears. If the swamp adjoined a lake, the coal may be replaced by claystone or carbonate rock. This is a change of rock type in a horizontal sense; a change that takes place at the same time rather than at different times, and is called a facies change. The transition of the Monongahela Group from mostly carbonate rock in Pennsylvania to sandstone and red beds in West Virginia is a facies change because the lake environment in Pennsylvania and the delta environment in West Virginia existed at the same time.

A hiatus is an interval or gap in the rock record for which there are no rocks to represent a given time span. Either the rocks were never deposited, or if they were deposited, they were eroded away sometime after deposition. The Pittsburgh area has many hiatuses. For example, sediment may accumulate in a stream channel while the flood plain is receiving no sediment at all. Thus no rock will exist on the flood plain to represent the time during which sedimentation was occurring in the stream. Channel cut and fill means that sediment was eroded away after deposition, thereby indicating a hiatus between the rock of the valley floor and the sediment that eventually fills the channel. Because of hiatuses the geologist cannot find a complete rock sequence in any one locality and must fit many areas together to obtain the total sequence.

V STRUCTURAL GEOLOGY

by

W. R. Wagner

Pennsylvania Geological Survey

Sediments do not remain unchanged throughout geologic time; they often undergo deformation that is sometimes mild and sometimes intense. When the deformation is intense, as it is at centers of areas of mountain building, the rock layers may be partially melted or altered to metamorphic rocks. The once sedimentary rocks of the Philadelphia area are now metamorphic as a result of intense heat and pressure generated during the formation of the Appalachian Mountains. Allegheny County also felt the effects of Appalachian Mountain building but in a much more subdued manner. Here, the rocks instead of being altered were merely arched, tilted, and broken. Structural geology is concerned with these changes in shape and continuity of the rock layers, and the kinds of structural changes that can be observed in the county are: 1) joints or fractures in the rocks, 2) faults or fractures along which movement has taken place, and 3) folds or bending of the rock layers.

JOINTS

Joints are fractures in the rocks along which little or no movement has occurred. In Allegheny County they divide the rocks vertically and are at nearly right angles to the sedimentary layering that horizontally separates the rocks. Figure 35 shows vertical jointing in a lower Glenshaw sandstone at Natrona (Locality 18) which gives the sandstone a blocky appearance. The joints are more widely spaced and better developed than the joints in the thin interbeds of shale and in the thicker shale unit underlying the sandstone. In the shales the joints are very close together and cause the shale to fall apart into tiny fragments on weathering. The horizontal bedding and the vertical jointing in the sandstone are crudely analogous to the horizontal and vertical divisions in the supporting stone wall in the lower right side of the figure.

Jointing in coal is called cleat. Two well-developed vertical and intersecting directions are developed as shown by Figure 36. These planar joints are the butt cleat and the face cleat. In mining, the face cleat is more pronounced than the butt cleat and usually produces continuous faces.

Joints are produced by unequal forces acting on the rocks, causing them to fracture in two main directions. One direction is northwest-southeast and the other is northeast-southwest; both directions can be seen in many outcrops (Nickelsen and Hough, 1967).

Joints are influential in landslide movements, weathering of rock, and flow of surface and subsurface water. The role of jointing in landslides can be observed at Brilliant Cut (Locality 38) where large blocks of rock, some the size of rooms, break away and slide down the cliff (Figure 31). These blocks can be identified by the layering which is no longer horizontal but is now dipping into the cliff. The dip of the layers is caused by rotation of the block during sliding. Water running down the joint planes weathers the rock behind the face of the cliff and when the rock is sufficiently weakened, it breaks off and slides. Several

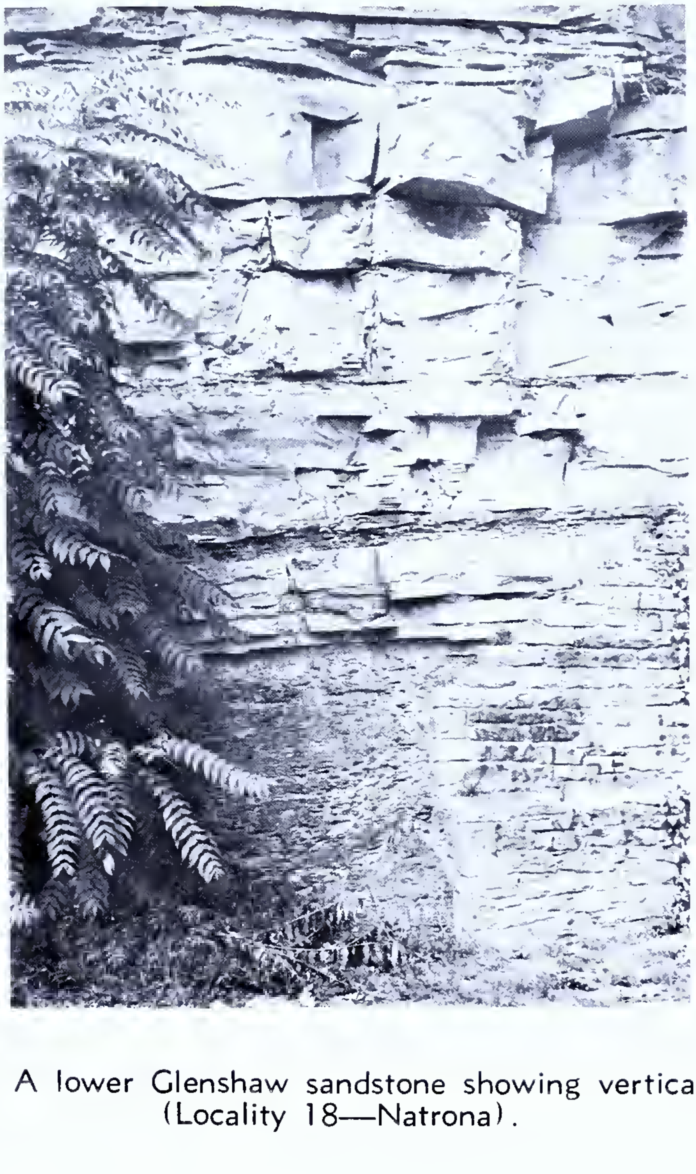


Figure 35. A lower Glenshaw sandstone showing vertical jointing. (Locality 18—Natrona).

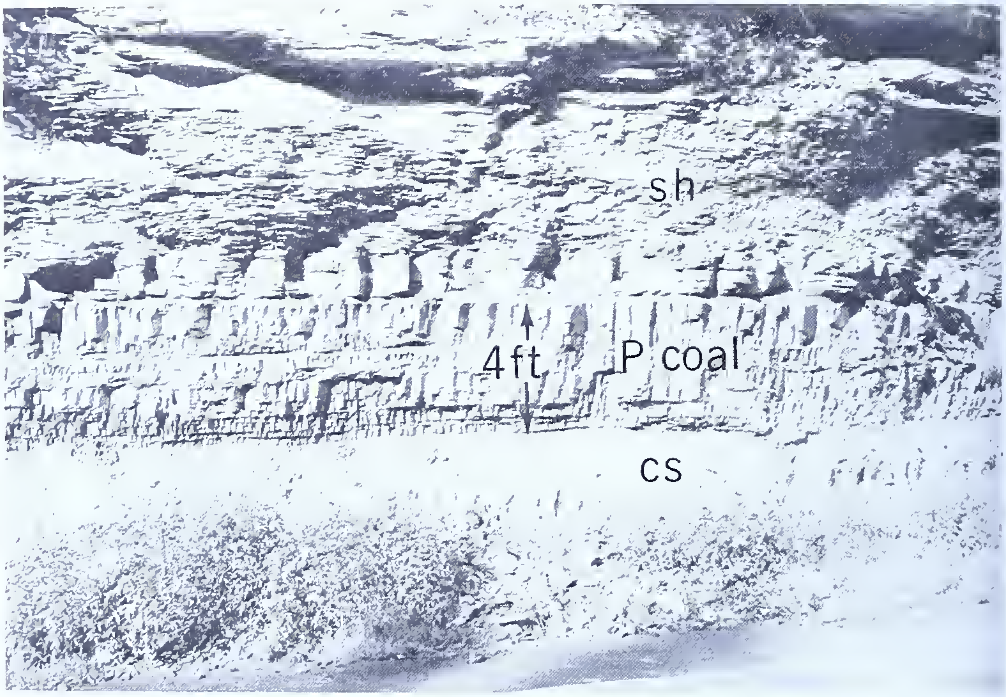


Figure 36. Pittsburgh coal (P coal) showing well-developed jointing. (Locality 22—Painters Run Road). Symbols: sh—shale, cs—claystone.

generations of slides at Brilliant Cut can be dated by the sizes of trees growing on the separate blocks. Weathering of joint planes is not the only cause of landslides; another common cause is plastic clay that moves when it becomes wet.

Slides relating to joints also occur along the Ohio River Boulevard east of Sewickley (Locality 5) and on Route 51 across the river from Sewickley (Locality 4). At these localities the main joint direction almost parallels the road thus creating a hazard when blocks occasionally break loose and slide into the road. The process of weathering behind the face of a cliff is a significant factor in the widening of a stream valley, but it is disastrous for preservation of property located on top of the cliff.

The major northeast and northwest joint directions are directions of weakness in the rocks and they influence the surface drainage. In Allegheny County many streams and rivers are oriented northwest-southeast and northeast-southwest. In subsurface a plentiful supply of ground water is more apt to be found where joint planes intersect than in the rock between joint planes.

FAULTS

Faults are rock fractures along which movement has occurred. The rocks on one side of the fracture have moved up, down, sideways, or diagonally with respect to the rocks on the other side. Faults can be recognized by their interruption of the orderly parallel pattern of rock layers. Several faults are present in the railroad cut across the Youghiogheny River from McKeesport (Locality 33). Figure 37 shows one of the faults where several sandstone layers above and to the right of a shack are abruptly cut off. The fault is a straight line running diagonally down the cliff from the upper left to the lower right as indicated by the marks on the edge of the figure. The rocks on the right side of the fault have dropped down a vertical distance of about 15 feet and the thin-bedded siltstones and shales above track level on the right side of the fault are found above the sandstone on the left side of the fault. Near the top of the cliff (not shown in the figure) is a green claystone which is not offset by the fault because the fault disappears before reaching

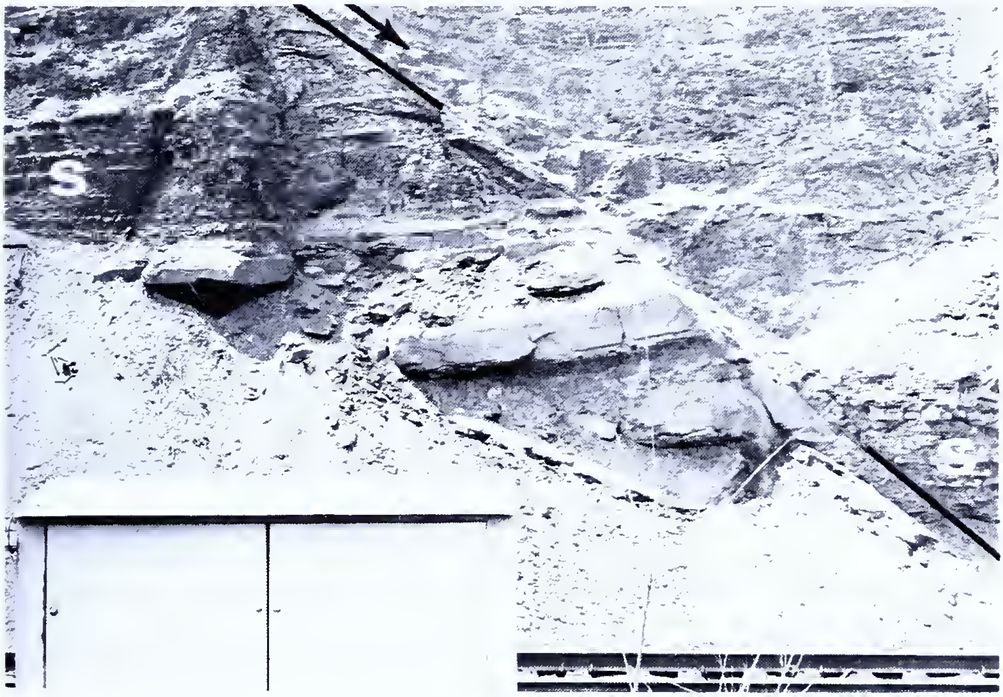


Figure 37. Faulting in lower Casselman Formation. Rocks on the right side of the fault have dropped approximately 15 feet with respect to the rocks of the left side of the fault. (Locality 33—McKeesport, west side of Youghiogheny River at Fifth Avenue Bridge. Several faults may be observed here). Symbols: S—shale and siltstone.

the green claystone. This means that the layers below the green claystone were deposited and faulted before the green claystone was laid down.

Possibly the most structurally complex area in Allegheny County is found along the B & O Railroad tracks at Bakerstown Station in Richland Township (Locality 1). In addition to faulting, tilted beds and an erosional surface are present. Figure 38 is an interpretation of the west wall of the railroad cut. The cut runs north-south and is separated into a southern and northern section by a 200-foot long retaining wall. The explanation of the northern section is taken from Ralph Ross's master's thesis at the University of Pittsburgh.

The individual rock units are numbered from one to nine; nine the youngest or last deposited, is the Morgantown sandstone. This rock sequence is interrupted by faults, most of them dipping to the north (to the right) except for the two on the south (or left) which dip to the south. Between faults the rock units are tilted so that the beds dip to the south at angles up to 45 degrees from the horizontal. The tilting causes the rock units to repeat themselves. For example, unit 4, the coal seam, is repeated three times, twice north of the retaining wall and once south of it.

The erosional surface at the base of the Morgantown sandstone (Unit 9) can be recognized by the occurrence of coal lenses near the contact, at places a basal conglomerate, and especially by the truncation of different rock units below the erosional surface.

Notice particularly that most of the faults enter and then disappear in the Morgantown sandstone. This fact means that the erosional surface is also faulted and that faulting took place after the formation of the erosional surface and during the time when the lower part of the Morgantown was being deposited. Faulting ceased before the end of Morgantown deposition.

Faulting, however, was not restricted to the time of Morgantown accumulation. It also occurred sometime during the formation of units one to eight. The maximum displacement during Morgantown time was about 15 feet, the amount being determined by how far the erosional surface was dropped in the second fault from the north end of the cut. On this same fault, however, the coal seam (unit 4) is offset approximately 45 feet. Subtracting from 45 feet the 15 feet of faulting during the Morgantown deposition leaves 30 feet of faulting to have taken place during deposition of units four to eight.

The faulting at Bakerstown Station is related to ancient landslides and stream erosion, a process going on today at Brilliant Cut where large blocks slide down the cliff along fault surfaces dipping toward the

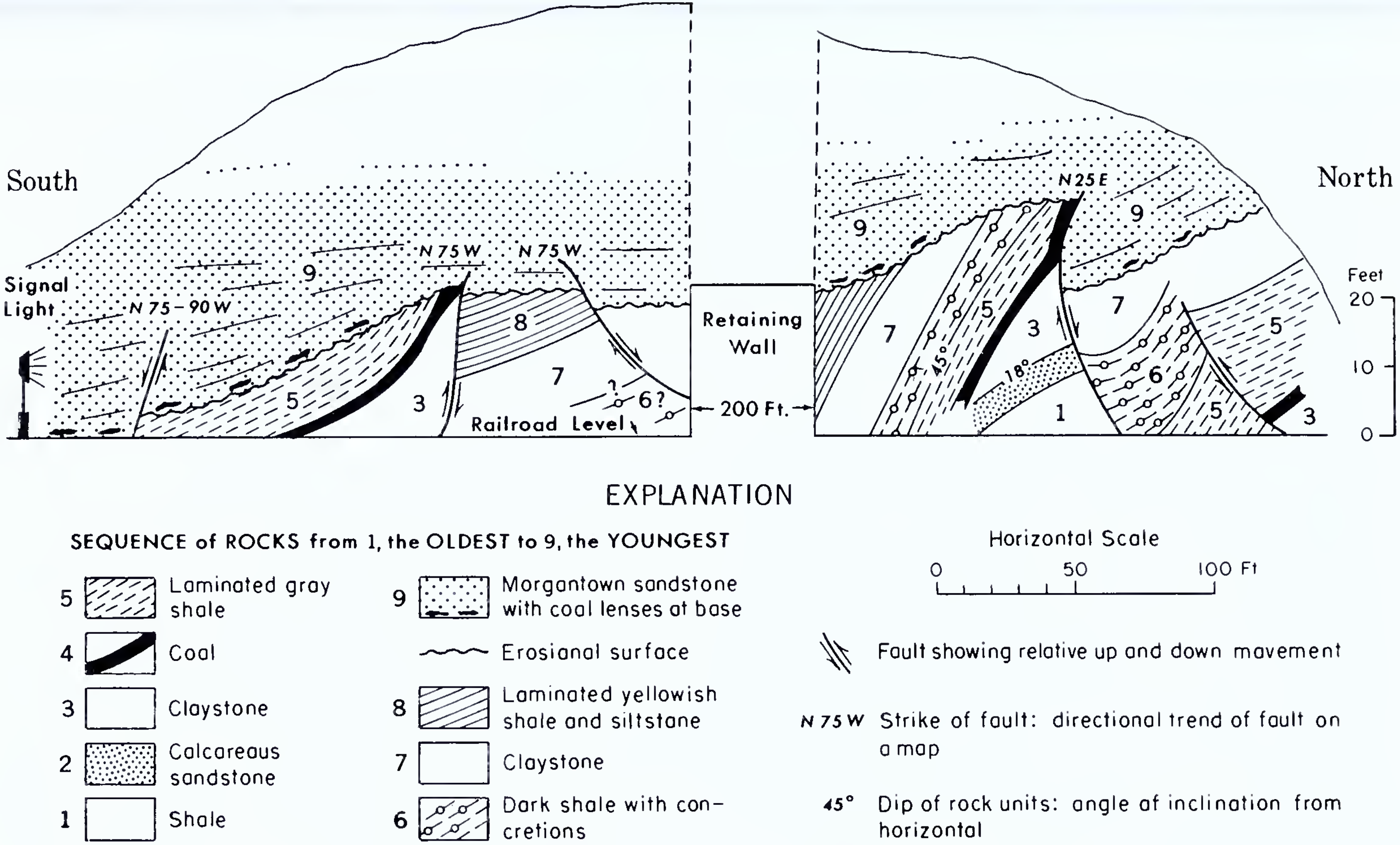

South
North
Signal Light
N 75 – 90 W
N 75 W
N 75 W
N 25 E
9
8
7
6?
5
3
1
45°
18°
Railroad Level
Retaining Wall
200 Ft.
Feet
20
10
0
EXPLANATION
SEQUENCE of ROCKS from 1, the OLDEST to 9, the YOUNGEST
5 Laminated gray shale
4 Coal
3 Claystone
2 Calcareous sandstone
1 Shale
9 Morgantown sandstone with coal lenses at base
Erosional surface
8 Laminated yellowish shale and siltstone
7 Claystone
6 Dark shale with concretions
Horizontal Scale
0
50
100 Ft
Fault showing relative up and down movement
N 75 W Strike of fault: directional trend of fault on a map
45° Dip of rock units: angle of inclination from horizontal

Figure 38. Faulting in Casselman Formation along B and O Railroad cut, Bakerstown Station (Locality 1). Adapted partly from Ross, 1933.

Allegheny River. At Bakerstown Station an ancient river probably lay to the north of Figure 38. By busily eroding its bed and banks, it scoured out a valley with steep and unstable slopes and large blocks broke loose from the south slope and slid northward into the valley. Because of block rotation along the curved fault surfaces the units all dip to the south.

FOLDS

Folds are bends in the rock layers. An upfold or arch is called an anticline and a downfold or trough is a syncline. Folds are the most common form of distortion of layered rocks and they develop as a reaction to compression in the earth's crust. Figure 39 represents a layer of rock folded into an anticline and syncline. The plane that bisects a fold into similar halves is the axial plane; the line where the plane intersects the ground surface marks the map axis of the fold and the cross-sectional axis occurs where the axial plane meets a cross-sectional plane. The outcrop of the rock layer is found where the folded layer intersects the ground surface and because of the hills and valleys, the outcrop, shown as a heavy dotted line, describes an irregular pattern. In the figure the layer has been eroded off the anticlinal axis and lies in the subsurface in the area of the synclinal axis. The outcrop occurs on the flanks of the fold.

Anticlines are not necessarily related to topographic hills and synclines do not always form valleys. The structural features are related to compressional forces within the earth whereas topographic features are the result of later erosional forces at the earth's surface.

Figure 40 is a cross section approximately paralleling Route 51 in southeastern Allegheny County, extending from Lewis Run on the northwest to past Elizabeth on the southeast (see Plate 1, Figure C for location of the section). The topographic relief is over 400 feet, from an elevation of 720 feet on the Monongahela River to over 1,100 feet on the hilltops. Shown on the section is the Pittsburgh coal which is folded into the Duquesne Syncline and Murrysville Anticline. The structural relief on the coal, measured vertically from the trough of the syncline to the crest of the anticline, is about 200 feet, only half that of the topographic relief. Thus, the topography tends to mask the minor folding that is present in the Pittsburgh area.

Folds come in three sizes: small, intermediate, and large. The intermediate folds like those in Figure 40 are the most common and their distribution in the county is shown on Plate 1, Figure C. Some of the more continuous folds have been named. The size of these folds, as measured by the horizontal distance from the axis of one anticline to the axis of the adjacent anticline, range from about two miles to less than 10 miles. Because of the relatively large size of the folds coupled with their low structural relief, the dip of the layers on the flanks of a fold

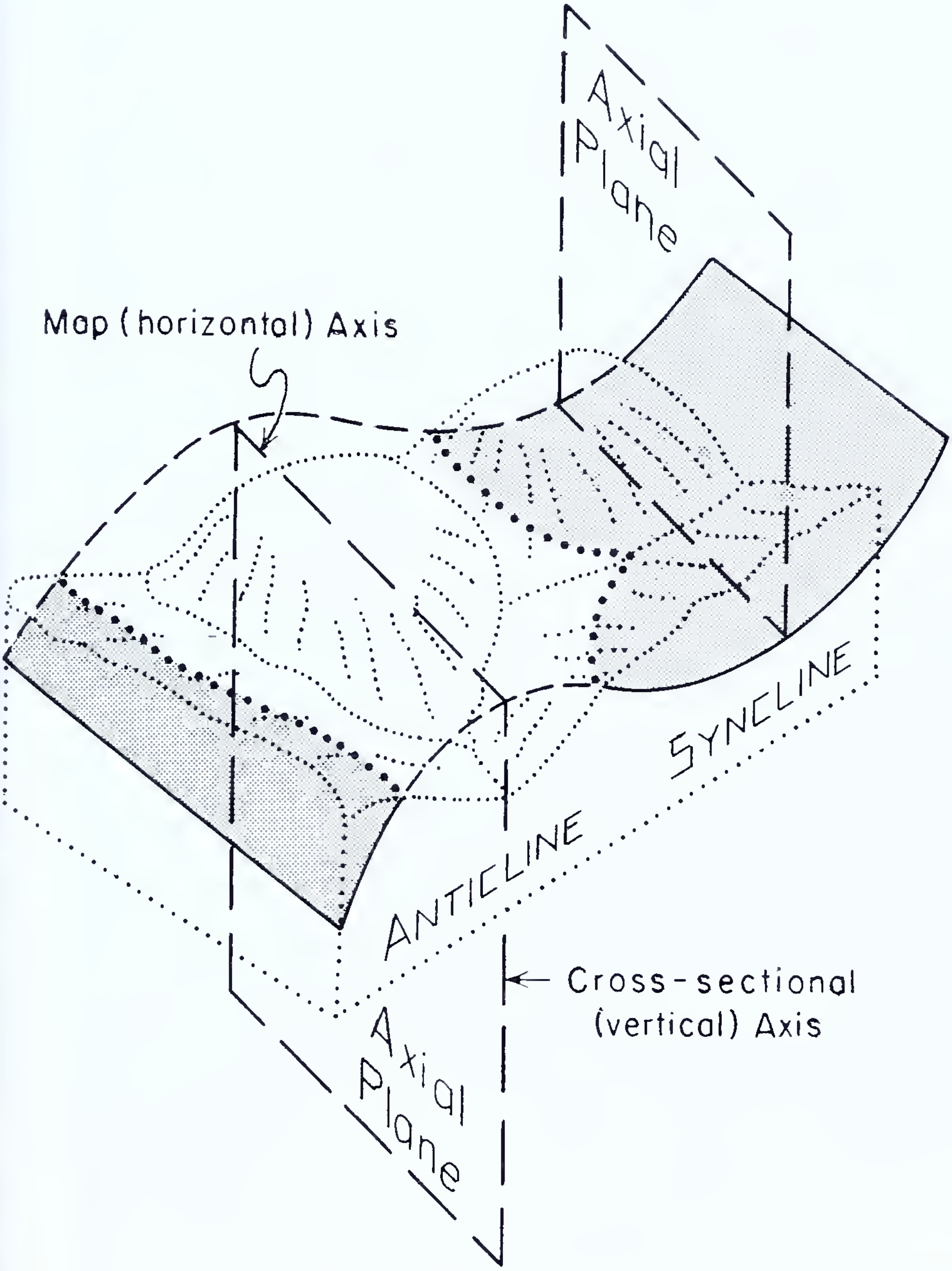


Figure 39. Dimensional elements of anticlines and synclines. Outcrop pattern is formed by intersection of the fold surface with the ground surface.

is very slight and usually difficult to perceive at most outcrops. One exception occurs along Route 8 north of Etna (Locality 13) where the Pine Creek limestone noticeably rises to the north toward the axis of the Kellersburg Anticline at Allison Park. The reason for the isolated exposure of rocks of the Allegheny Group at Allison Park is that at Allison Park a topographic low, the valley of Pine Creek, crosses the Kellersburg Anticline where the Allegheny rocks are at their highest elevation on the axis or crest of the fold.

In several places in the county small folds may be observed whose dimensions are in feet rather than miles. Figure 41 shows a small, well-formed anticline on Ohio Boulevard between Glenfield and Haysville (Locality 5). Another small anticline occurs at Duff City, Franklin Township (Locality 2). Many small folds are created by man during coal mining. Removal of underground coal pillars causes the overlying layers to collapse and form angular folds such as the one shown in Figure 42.

The large folds are tens of miles across. To appreciate their existence an area much larger than Allegheny County must be examined. Figure 43 is a map of the three state area of northern West Virginia, southeastern Ohio, and southwestern Pennsylvania. Structurally, southwestern Pennsylvania is part of a much larger feature in which the outcrops of the stratigraphic groups, the Dunkard to Allegheny, are arranged in a roughly concentric pattern. At the center of the pattern lies the Dunkard Group, the youngest rocks, and outward from the center the rocks become progressively older as one crosses from Monongahela to Conemaugh to Allegheny age rocks. Such a configuration, with the youngest rocks at the center, defines a basin which has been truncated by erosion. A basin has

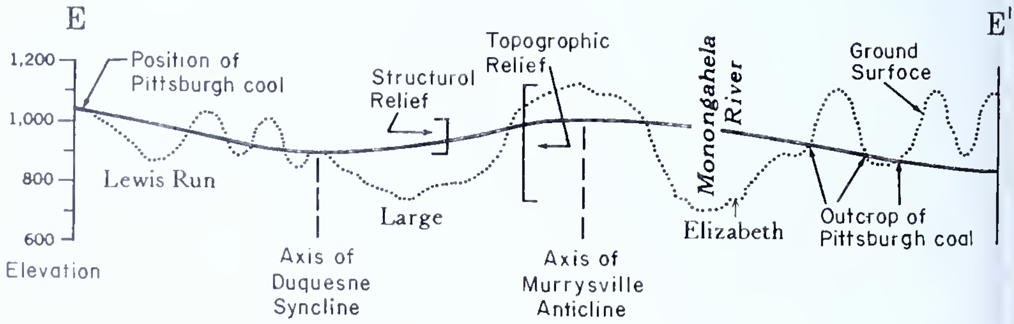


Figure 40. Section along Route 51 from Lewis Run to past Elizabeth. Section crosses Duquesne Syncline and Murrysville Anticline and relates structural relief to topographic relief.

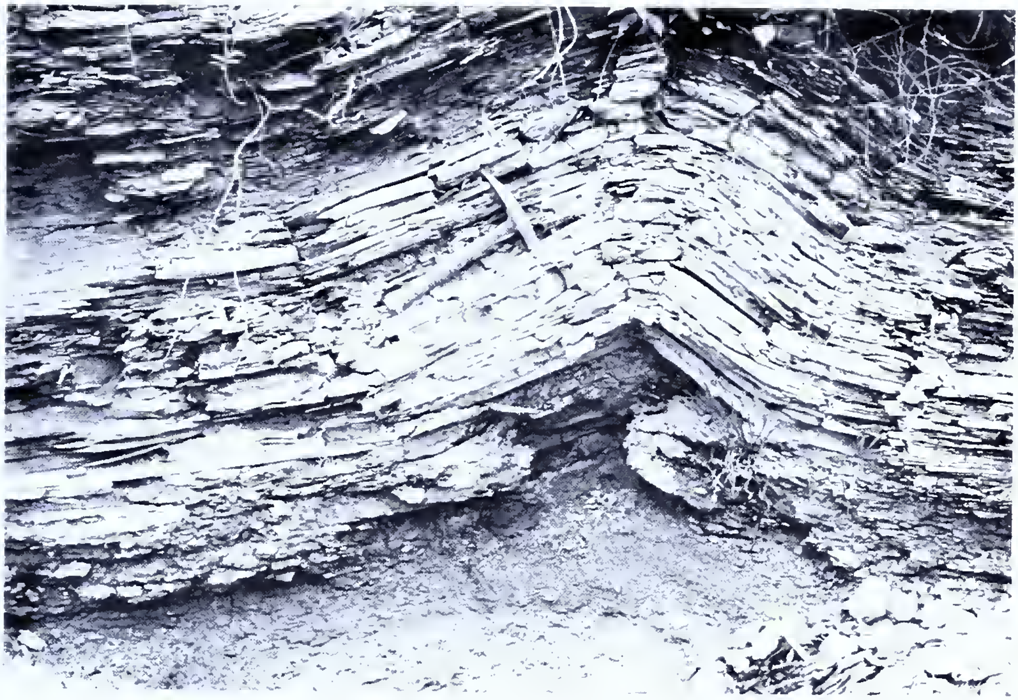


Figure 41. Small, naturally formed anticline. (Locality 5—Ohio River Boulevard between Glenfield and Haysville.

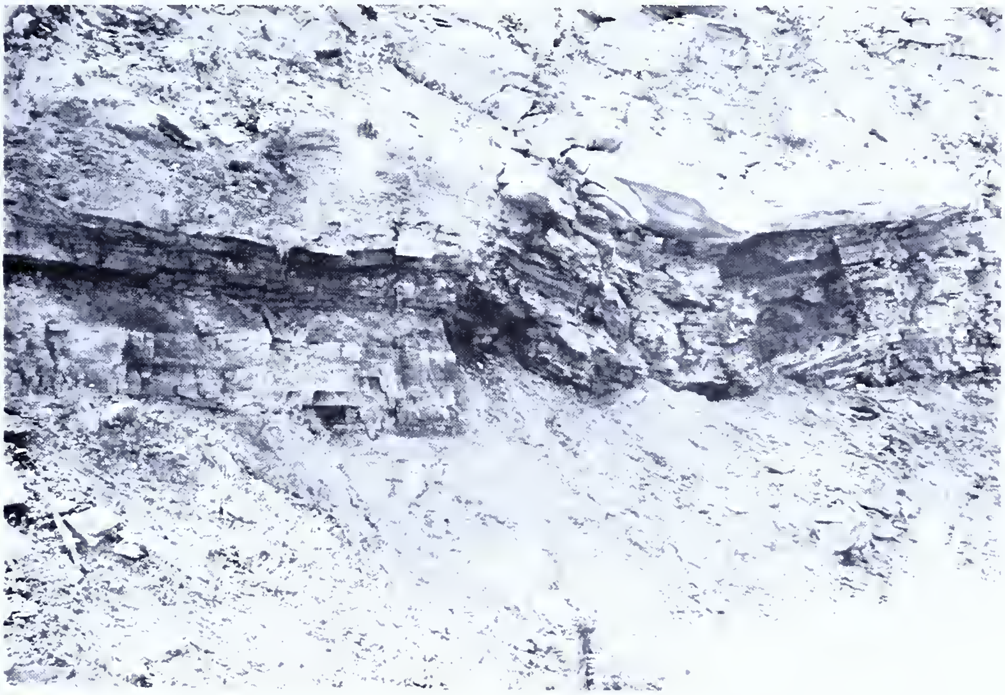


Figure 42. Small syncline in Pittsburgh coal formed by collapse of roof coal after mining out the main bed. (Locality 27—Route 51 near junction with Route 88).

a synclinal shape in any cross-sectional direction because the layers dip toward the center from all directions. The cross section F-F′ through the basin shows the layers dipping into the center. If a cross section

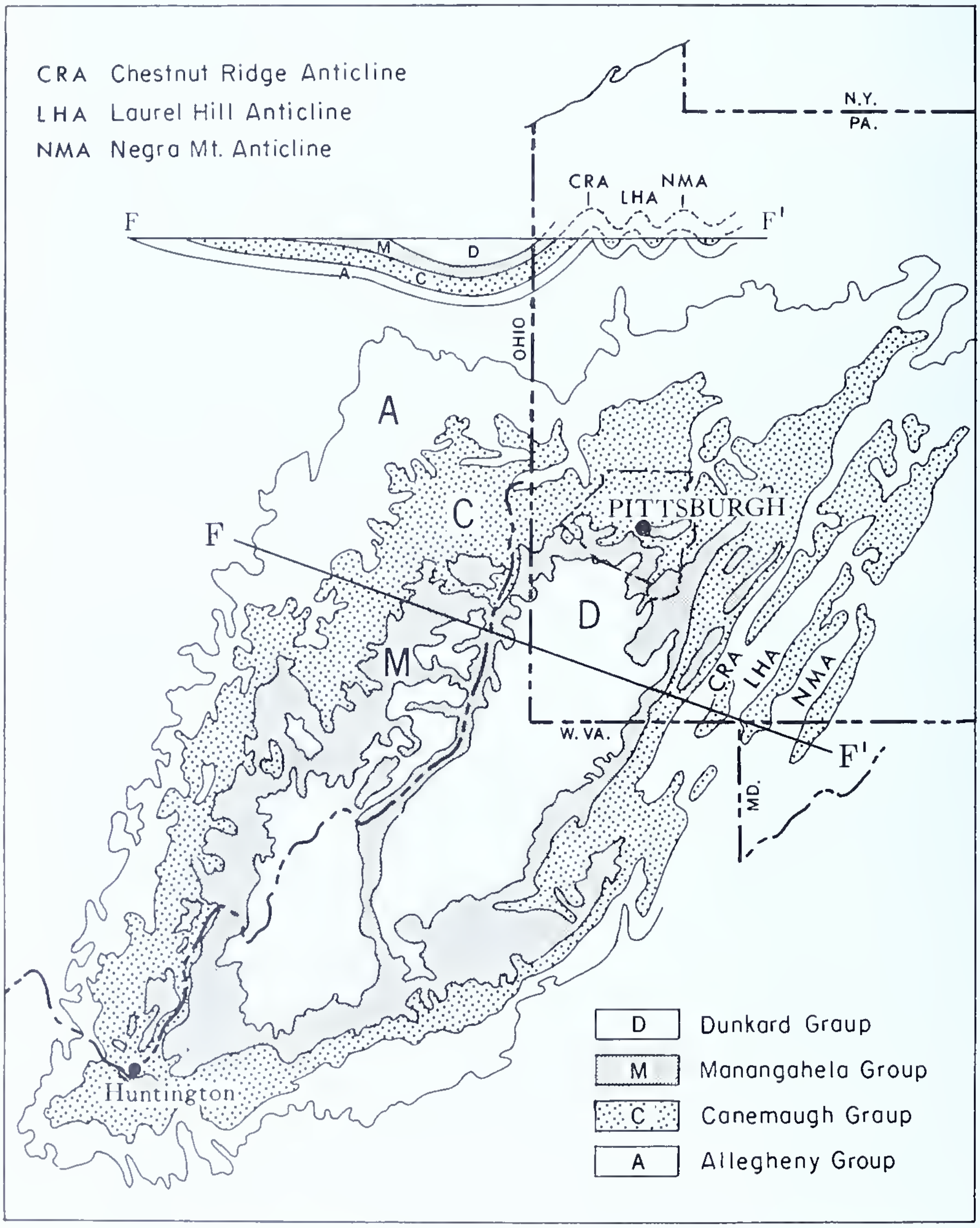


Figure 43. Geologic Map of the Pittsburgh-Huntington Basin. Adapted from U. S. Geological Survey and U. S. Bureau of Mines, 1968, Pl. 2.

were drawn along the axis of the basin, from Huntington, West Virginia at the southwest end to Pittsburgh at the northeast end, it would look similar to section F-F′ but the center of the basin would lie in northern West Virginia. The basin has been named the Pittsburgh-Huntington Basin. Because Pittsburgh lies near the northeast end of the elongated basin, the rock layers must dip gently to the south and southwest. This explains why the Allegheny rocks at the surface in northern Allegheny County are located below the surface in the southern part of the county.

The eastern end of section F-F′ is wrinkled into three anticlines and three synclines of intermediate size. These three anticlines from west to east are Chestnut Ridge, Laurel Hill, and Negro Mountain. In these three cases, the anticlines also happen to be topographic mountains which lie between Pittsburgh and the Allegheny Mountain Tunnel on the Pennsylvania Turnpike.

The Pittsburgh-Huntington basin was formed long after the rocks which compose it were deposited. The Pittsburgh coal and other rocks of the Monongahela and Dunkard Groups are still present because the basin, being structurally low, preserved them. Elsewhere these groups lie on structurally higher ground and were eroded.

VI FOSSILS

INVERTEBRATE AND PLANT FOSSILS

by

W. R. Wagner
Pennsylvania Geological Survey

The rocks of Allegheny County contain a variety of fossils. One may collect in abundance the shells of marine invertebrates that lived in the area when it was dominated by the open water environment previously discussed. A collector may find numerous carbonized plant fragments that were preserved in the stream and delta environment. Also, but less common, are vertebrate remains, such as fish bones and scales and amphibian and reptile bones that occur in strata deposited in lake and delta environments. Invertebrate and plant fossils are illustrated (Figures 44 to 51) and briefly described in this section, and the vertebrates are discussed in the following section.

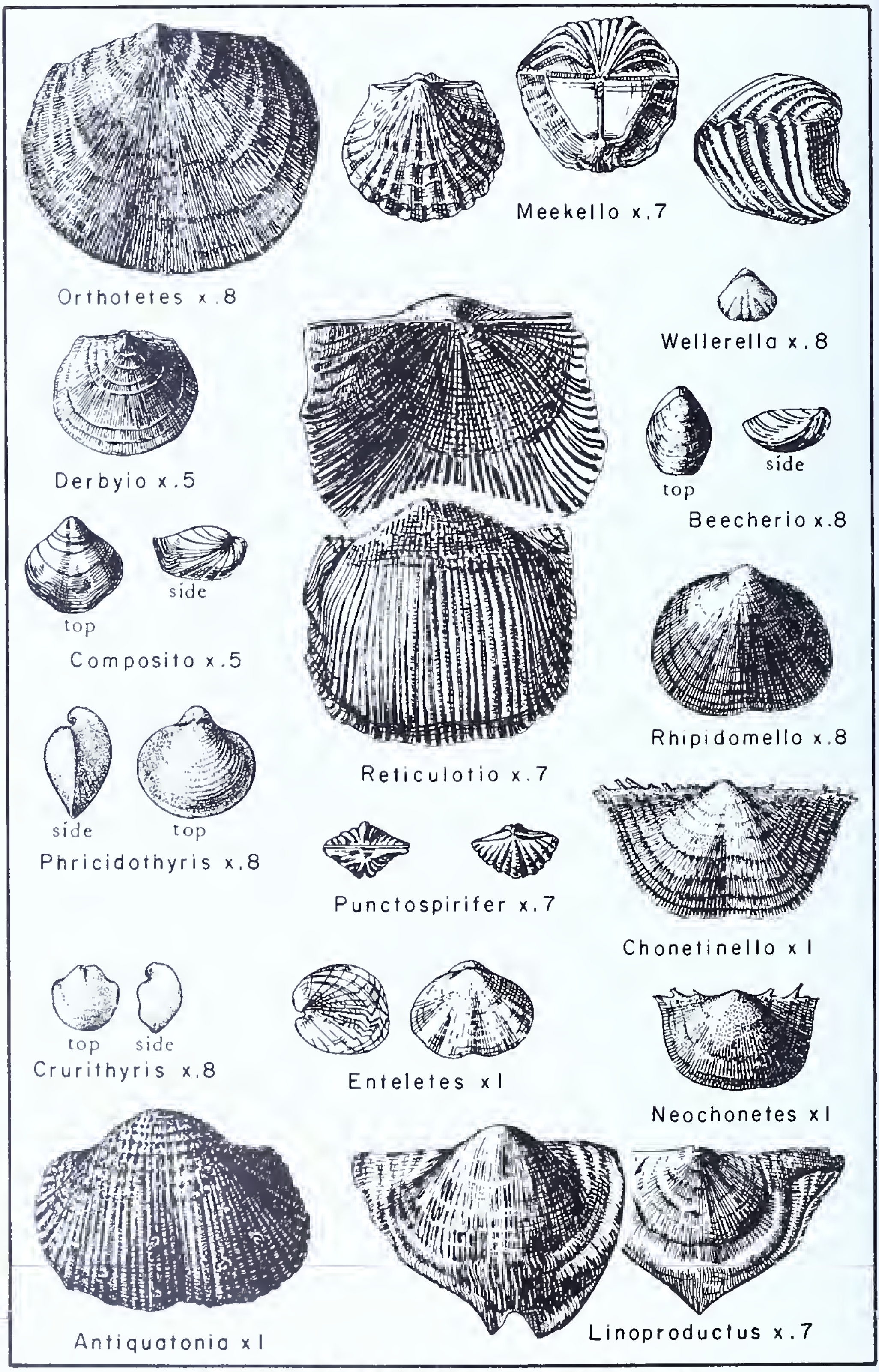


Figure 44. Brachiopods (lamp-shells).

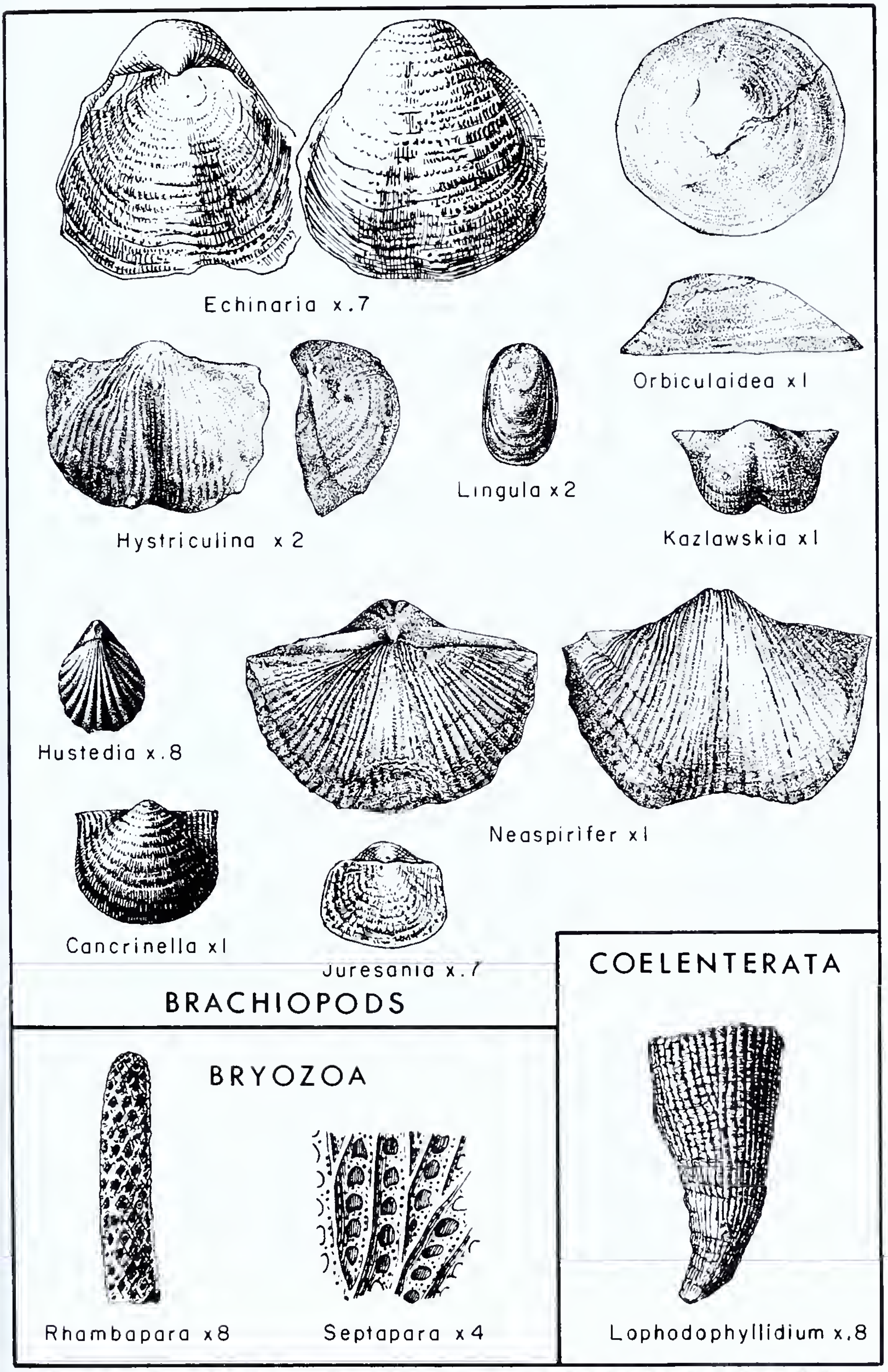


Figure 45. Brachiopods, Bryozoa, and Coelenterata (corals).

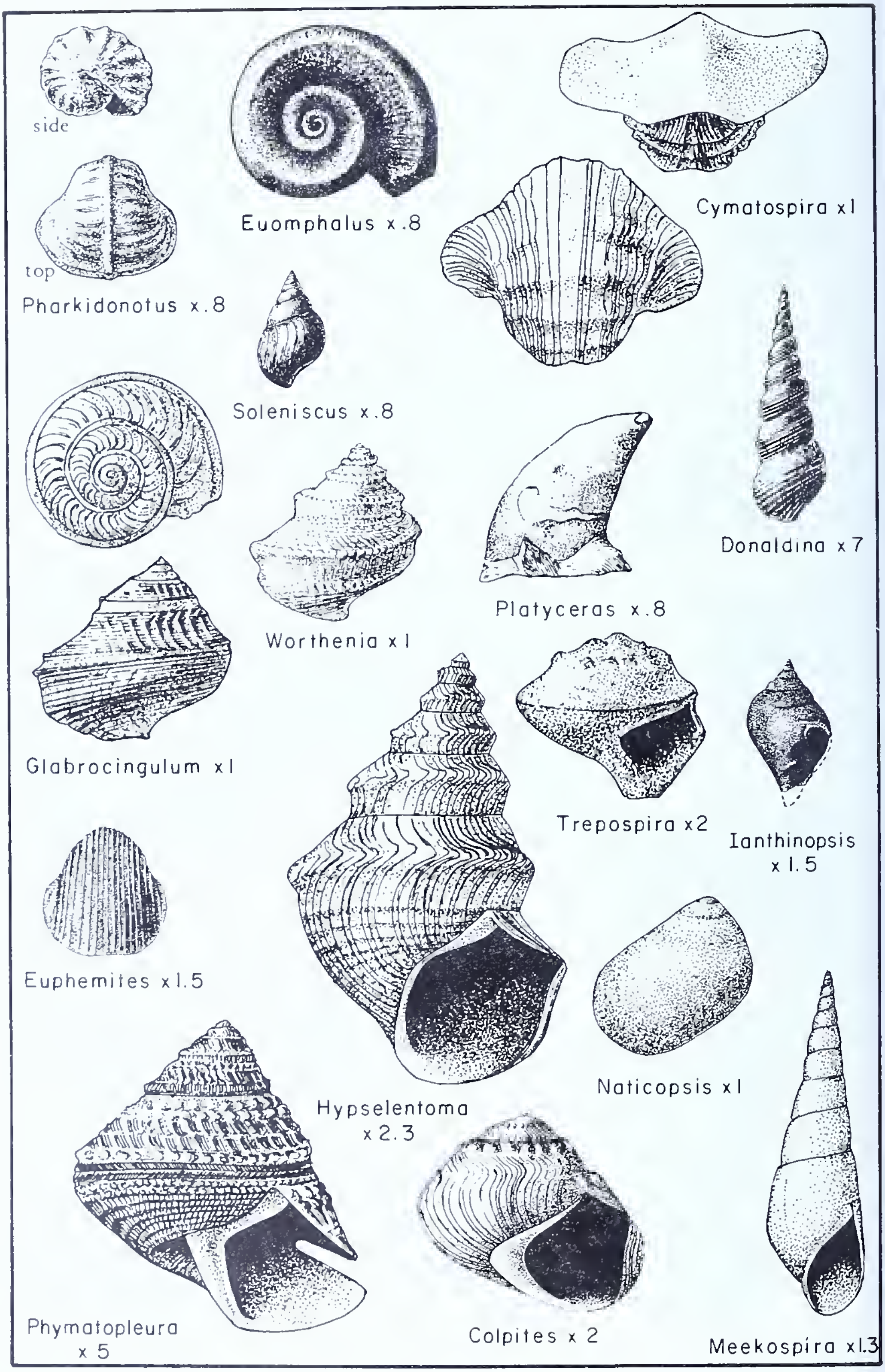


Figure 46. Gastropods (snails).

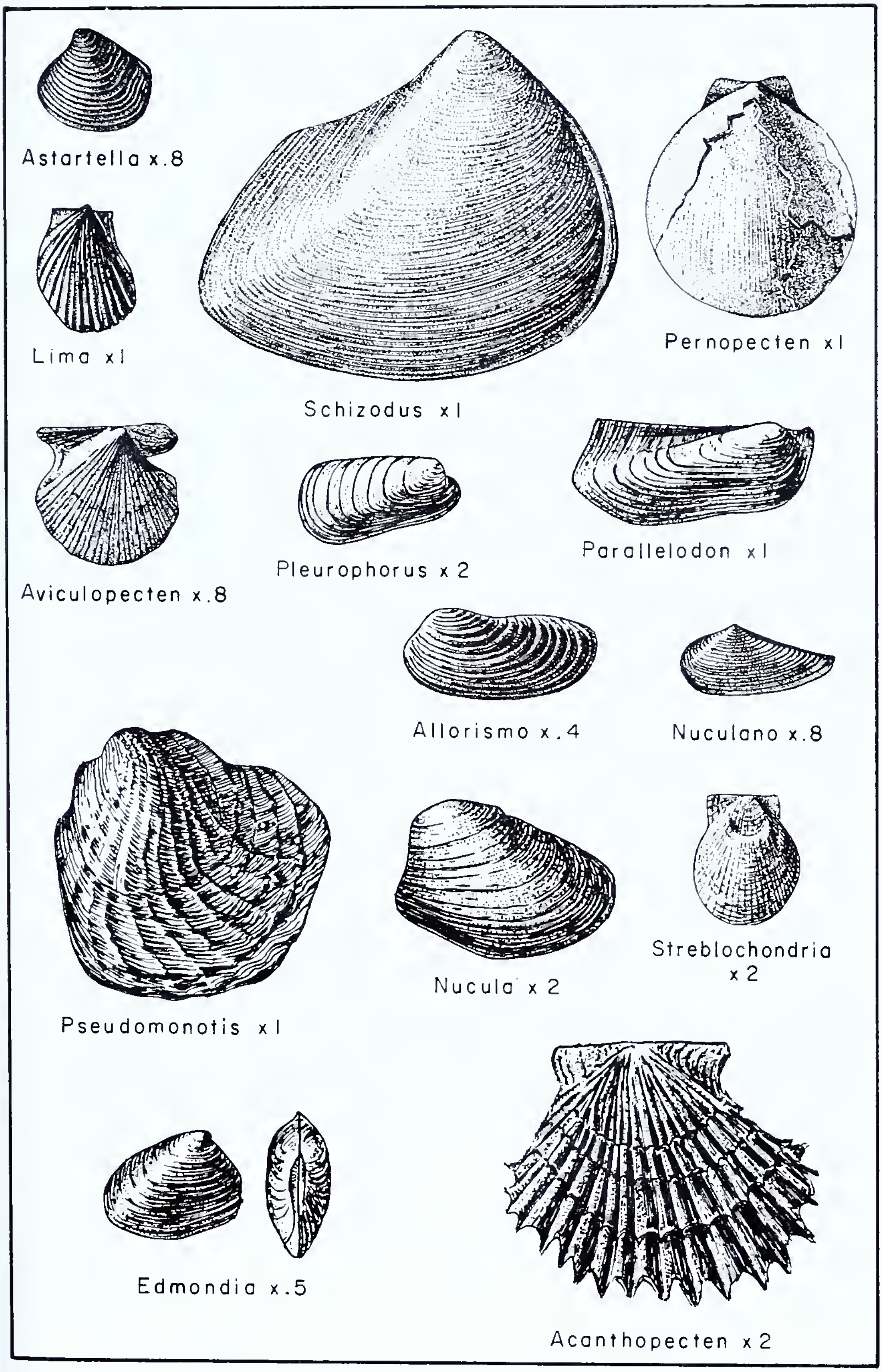


Figure 47. Pelecypods (clams).

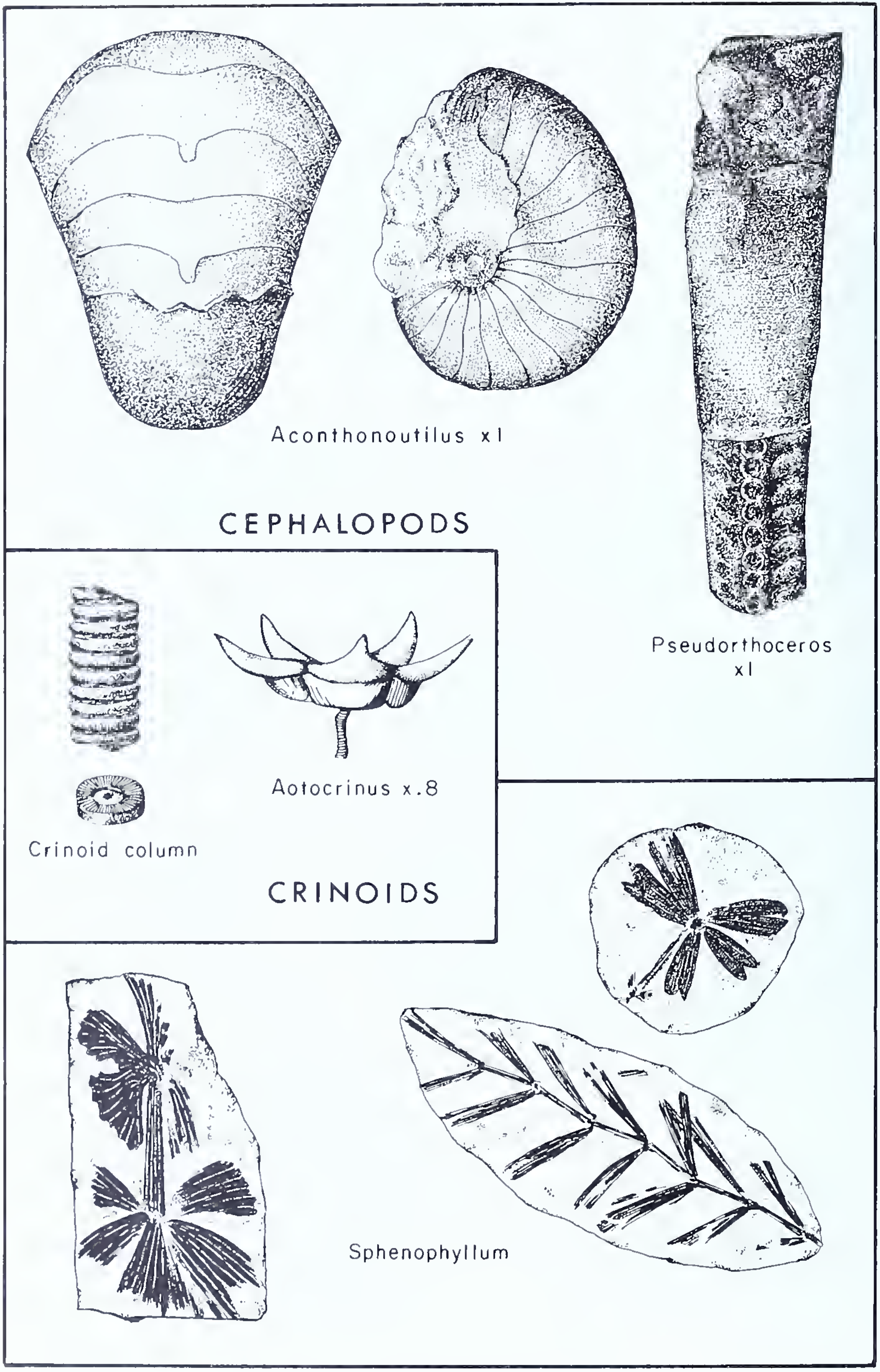


Figure 48. Cephalopods, Crinoids, and fossil bush (fossil bush from Edmunds and Koppe, 1968).

Outcrops of the thin, marine Ames, Woods Run, Pine Creek and Brush Creek limestones commonly contain a multitude of shell fragments of marine invertebrates. Figures 44 to 48 show many of the shells that can be extracted from these limestones. The symbol X. at each shell indicates the size of the illustration with respect to the actual shell. For

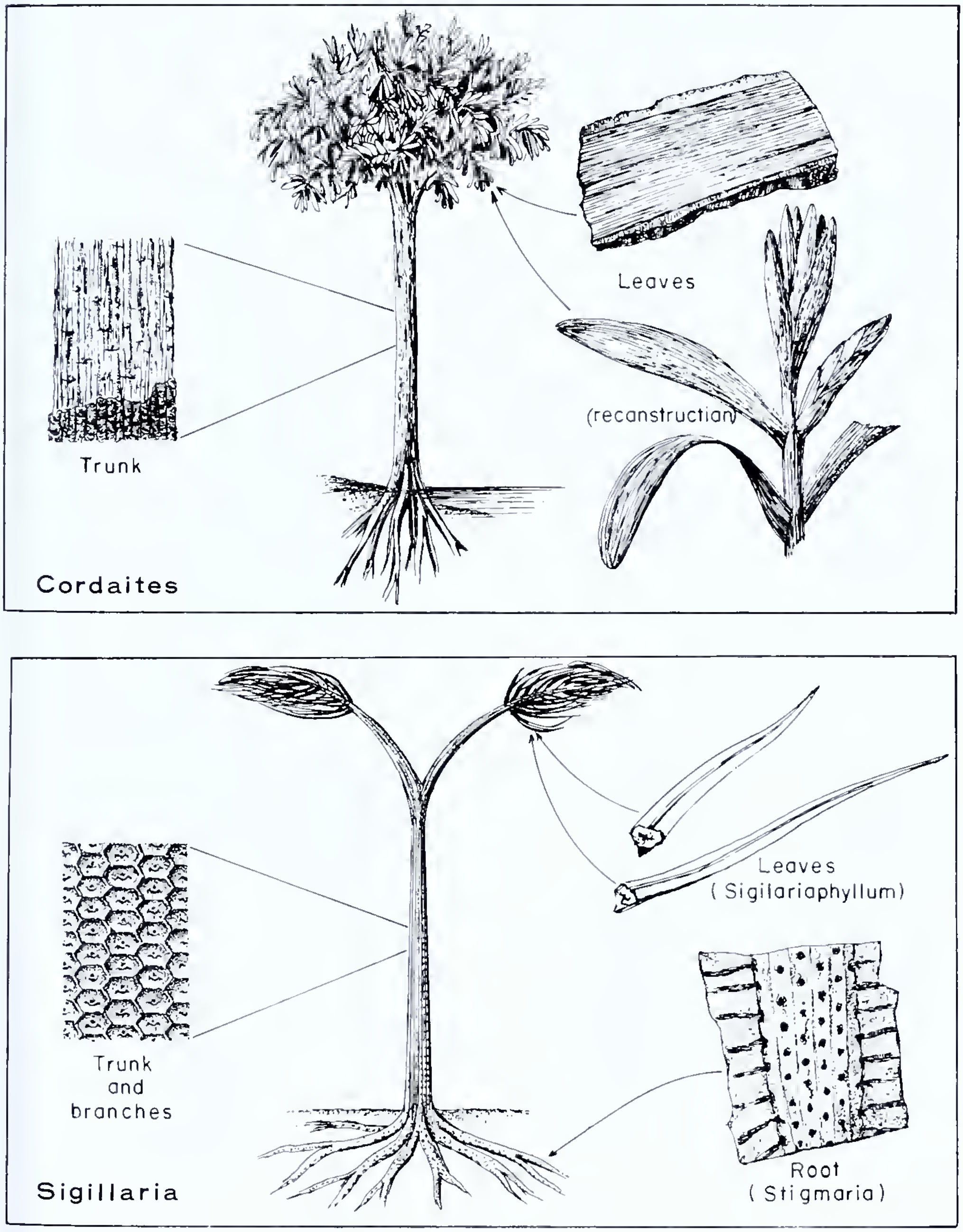


Figure 49. Fossil trees showing characteristics of trunks, roots, and leaves. From Edmunds and Koppe, 1968.

example X.7 means that the illustration is only $\frac{7}{10}$ as large as the actual shell.

The best collecting occurs in the more shaly parts of the limestone where the calcite shells, being more resistant than the clayey matrix, weather out of the crumbling rock. In purer carbonate layers the rock

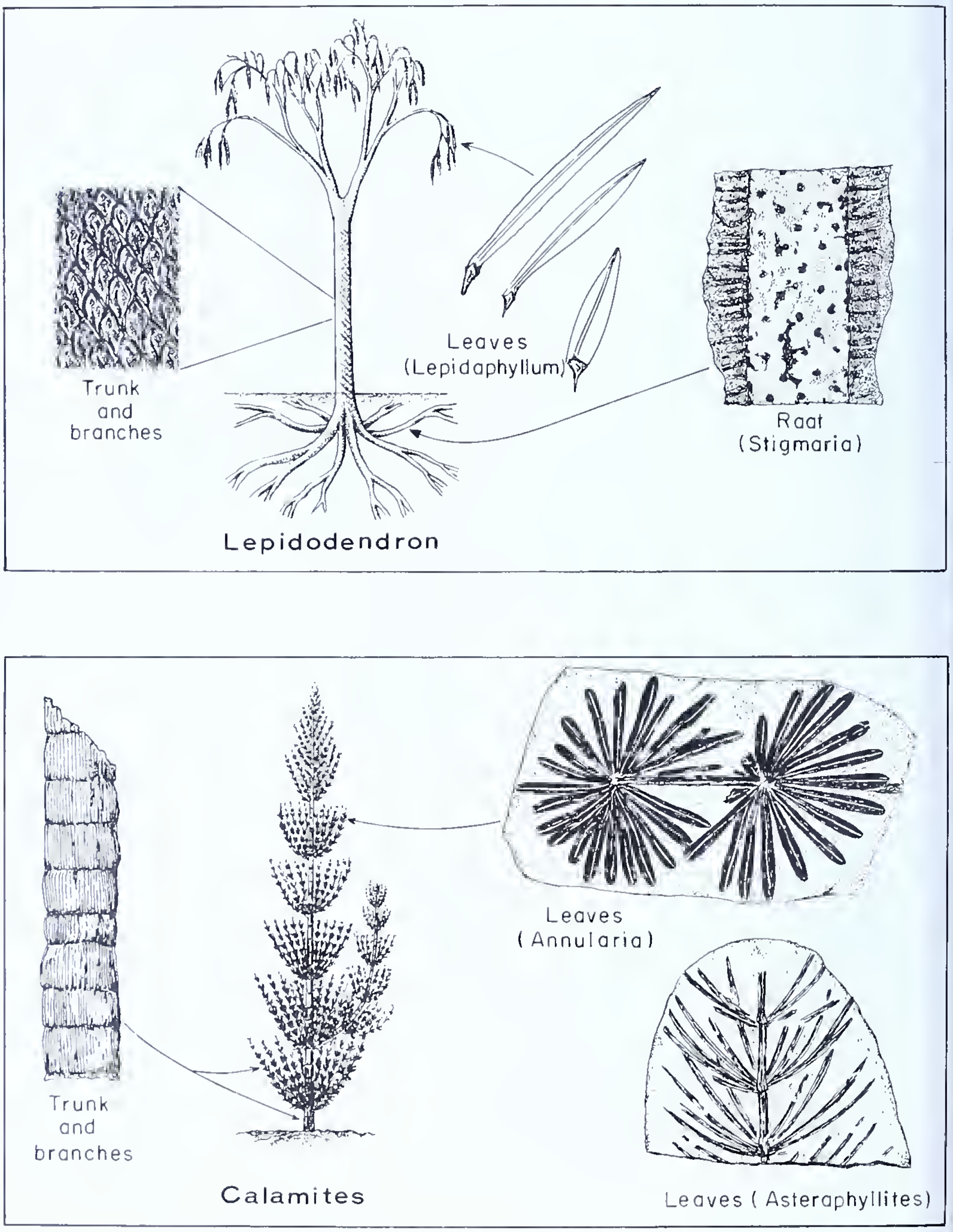


Figure 50. Fossil trees showing characteristics of trunks, roots, and leaves. From Edmunds and Koppe, 1968.

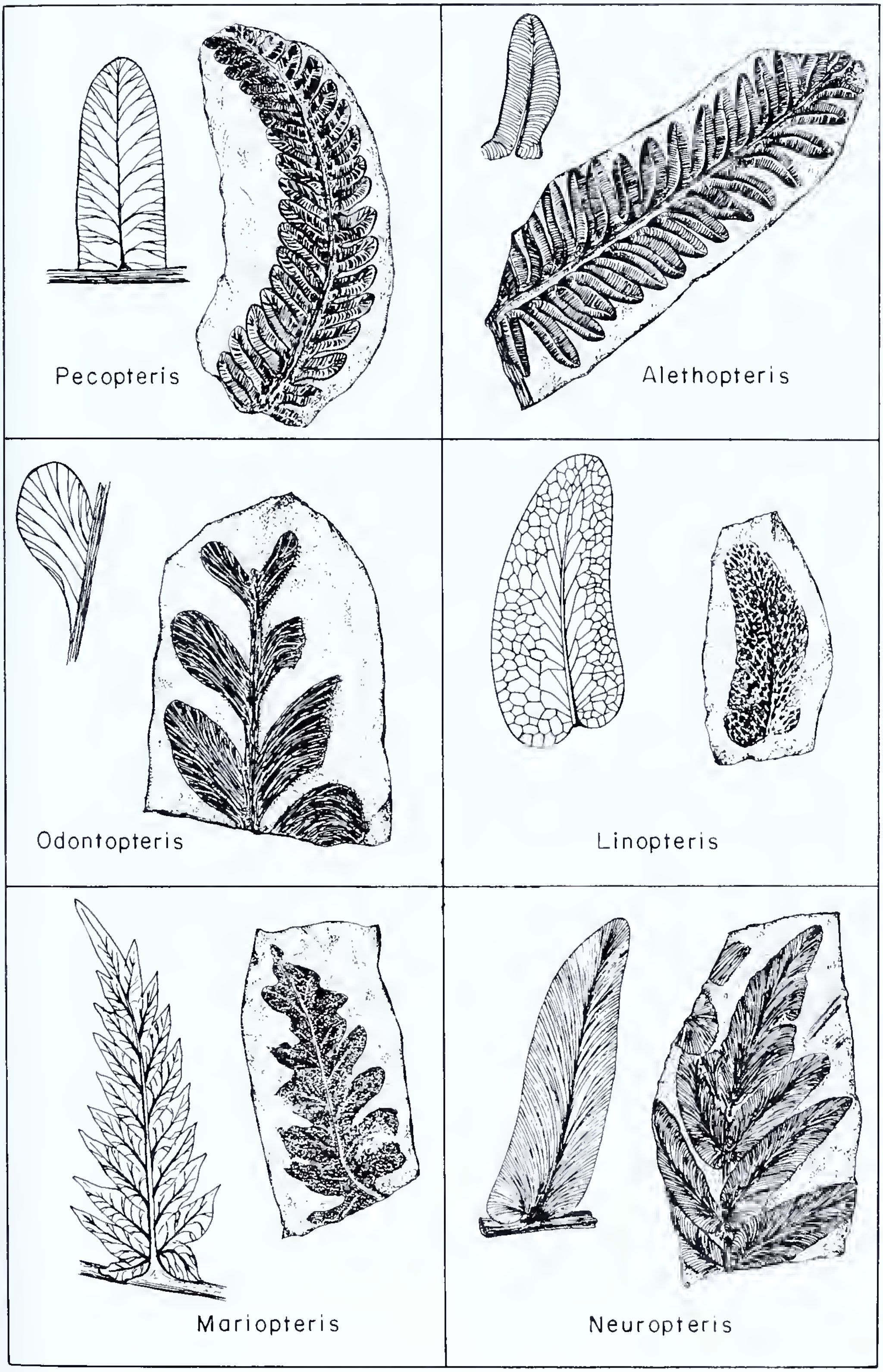


Figure 51. Fern and fern-like leaves. From Edmunds and Koppe, 1968.

is as resistant as the shells, and the shells commonly break when one attempts to remove them from the rock.

Usually, shell fragments are easy to find; more diligent searching is required to locate the whole or almost complete specimens illustrated in the figures. The most common invertebrates are brachiopods (lamp-shells), crinoid columns (Figure 48), and the coelenterate, Lophophyllidium (a coral on Figure 45). Bryozoans are plentiful in the Pine Creek limestone.

For further information on the classification and habitat of these invertebrates, the reader is referred to Bulletin G40 of the Pennsylvania Geological Survey, *Fossil Collecting in Pennsylvania.*

With the invertebrate fossils only the shells are preserved as evidence of their former existence, but with plants, the roots, the trunk and branches, and the leaves may survive. The problem of the paleontologist is to associate the leaves with the correct trunk and roots because the various parts become scattered among the sediments during deposition. Figure 48 pictures the branches and leaves of the fossil bush, *Sphenophyllum* Figures 49 and 50 show the roots, branches and leaves of some of the Pennsylvanian trees. The leaves of the ferns and fern-like plants are illustrated in Figure 51.

Black, filmy carbonized impressions of leaves may commonly be found in the platy shales above coal seams and in the dark shales of floodplain and lake deposits where the leaves fell into water and were buried in mud. Trunks and roots may be observed as impressions in stream and channel sandstones.

FOSSIL VERTEBRATES FROM THE PITTSBURGH AREA

by

Richard Lund
University of Pittsburgh

The fossil remains of vertebrate animals are relatively common in Allegheny County, but tend to be overlooked by the uninitiated. They are rarely found as whole skeletons, but usually as disarticulated parts which have become separated from each other by agents of decay and by water currents prior to burial and fossilization. Fish, amphibian and reptile remains are most commonly teeth, then scales, then bones.

When searching for vertebrate fossils, therefore, one looks for such parts as scales and teeth, in sediments typical of quiet water deposition such as fine-grained black shales, cannel coal pockets, or fresh-water limestones. Shales often must be split with a chisel-type hammer to reveal the enclosed fossils, whereas fossil bones may project from the weathered surfaces of limestones. Where a shale has yielded many isolated fish scales, patient searching may uncover an occasional scientifically important articulated specimen which was the source of the scales.

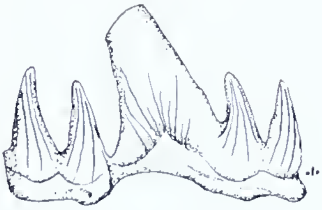
In the Allegheny Group, whole small bony fish, as well as many isolated scales, were found in a cannel coal near Cannelton, Beaver County. Similar preservation in a cannel coal under the Upper Freeport coal in nearby Ohio yielded a tremendous variety of small bony fish, shark teeth and spines, lungfish bones, coelacanths (a lobed-finned fish of the Paleozoic and Mesozoic Eras) amphibians and reptiles, which had lived in a lake and been buried in plant debris shortly after death. Neither of these localities is now accessible, as the mines associated with them closed at the beginning of this century.

Scales of the same type of bony fish may be found in several cannel coals and coal shales in Beaver County, as well as at the horizon of the Mason Shale (a shale below the Brush Creek limestone) in western Allegheny County. Coelacanth scales may be found in black, iron-stained shales in a railroad cut in Jeannette, Westmoreland County, only a few feet above the Upper Freeport coal.

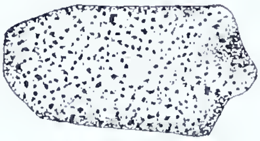
The Glenshaw Formation of the Conemaugh Group is characterized by the presence of several typical cyclothems. The fresh-water shales (Mason) lying below the Brush Creek marine beds, and the fresh water shales below the Woods Run marine limestone have both produced fish remains. Scales and teeth of small bony fish, occasional two-pronged pleuracanth shark teeth, and several sorts of small shark spines may be found by the dedicated searcher. The bones are usually concentrated in the finest-grained, blackest shales, and may be distinguished from plant fragments by the presence of a glossy enamel coating, blackened by mineral staining.

All marine limestones in the Glenshaw Formation have yielded fossil fish material. The "Cladodus" teeth (Figure 52) have one tall central cusp, flanked by two to three progressively shorter cusps on either side in a line upon a bony base, and come from a fish-eating shark. Gently curved plates with finely pitted surfaces are *Deltodus* teeth, adapted for crushing hard-shelled invertebrates such as brachiopods. Teeth of this type lay like a pavement in the jaw of a shark-like fish, and are designed for crushing hard shelled animals such as brachiopods and snails. *Campodus* is from a fish with similar dietary preferences, and *Petalodus* had several rows of these chisel-like teeth in the front of its mouth, and presumably flatter, crushing teeth in the back of its mouth. Traces of other fish which include scales and teeth of minnow-sized bony fish, may only be found by dissolving blocks of the rock in acid. It is not surprising that most of the large fish found in the marine limestones were feeders upon the plentiful supply of shelled animals we still see today.

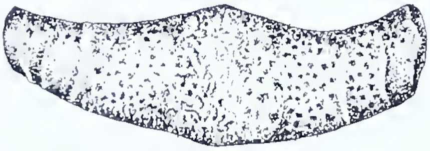
The bones of several large amphibians and reptiles were found in the



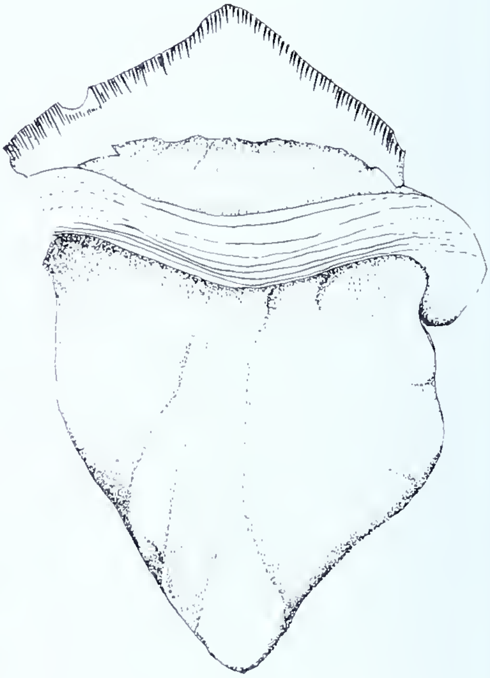
Cladodus



Deltodus

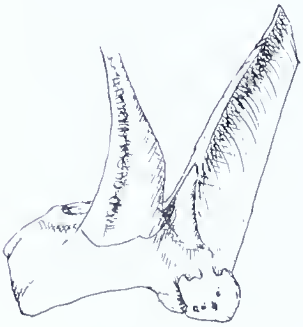


Campodus

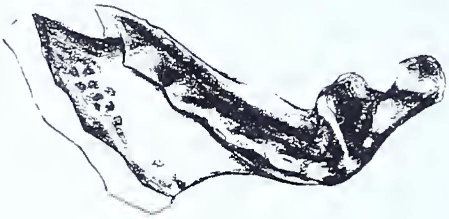


Petalodus

Acanthodes



Orthacanthus



Lungfish jaw

Figure 52. Fossil vertebrate remains. All figures are X 1 1/3 except lungfish jaw which is X 14.0.

Turtle Creek valley around 1910 in a red and gray claystone (Pittsburgh reds) immediately below the Ames limestone. The bones found included parts of *Desmatodon,* a reptile-like amphibian, the finback mammal-like reptile *Edaphosaurus,* and the large amphibian *Eryops.* Diligent exploration may result in the rediscovery of this locality.

Nearly thirty feet above the Ames limestone is found a sequence of fresh water limestone, the Duquesne limestone (see Figure 25, Geologic section), which is extremely rich in vertebrate remains. Among the larger bones likely to be visible without a hand lens are the spines of *Acanthodes* (Figure 52), the teeth and spines of *Orthacanthus,* a large fresh-water shark, and the bones of *Sagenodus,* a large lungfish. Many forms of fish and amphibians which were preserved in this limestone may only be found by dissolving the rock in acid and sifting the residue under a microscope. One such bone, illustrated in Figure 52, is the lower jaw of an eel shaped lungfish related to the modern African lungfish.

The jet black shale lying above the Duquesne limestone also contains the remains of many fish. By carefully splitting the shale, one may find hundreds of small, rhomboidal scales of the bony fish *Elonichthys,* and many other bones of this and other fish (Locality 15). Occasionally it is possible to find patches of scales which indicate that the remainder of the fish may be present within the rock. It is only possible to recover these fish by using a microsandblasting machine, one of the tools of a professional paleontologist.

A sequence of gray shales, immediately below the Pittsburgh coal, commonly contains relatively large, ornamented bony fish scales. Underlying these shales are thin-bedded fresh-water limestones which usually contain only the tiniest of fish scales and teeth. However, an old quarry in these limestones on Herron Hill yielded the skulls of several types of very grotesque amphibians, pieces of reptile skeleton, and bones and teeth of *Sagenodus* and *Orthacanthus.* These bones were concentrated in one spot, where they were found by Carnegie Museum field workers in the nineteen thirties. The quarry has since been covered by a housing project, and further knowledge of these animals awaits a new discovery.

Very little scientific work has been done on the fossil vertebrates of southwestern Pennsylvania. In the search for these fossils, a sharp eye, a good hand lens and a great deal of patience are necessities. Great care should be used to insure that rocks collected from different layers, even at the same locality, be kept carefully labelled, as each layer represents a specific interval of time. Accurate labels should accompany each specimen.

If a vertebrate fossil is found which seems to be unidentifiable and interesting, Carnegie Museum will be happy to identify and explain the find.

VII HISTORY OF PITTSBURGH'S RIVERS

by

Louis Heyman
Pennsylvania Geological Survey

The Appalachian plateau of western Pennsylvania is drained by two major river systems: the Susquehanna River drainage in the eastern part of the plateau and the Ohio River drainage in the western part (Figure 53). The Susquehanna drainage empties into Chesapeake Bay and then into the Atlantic Ocean whereas the Ohio River drains into the Mississippi River which flows into the Gulf of Mexico.

An anomalous feature of western Pennsylvania drainage is that no major river enters Lake Erie. In fact most tributaries only ten miles south of the Lake are part of the Ohio River drainage rather than part

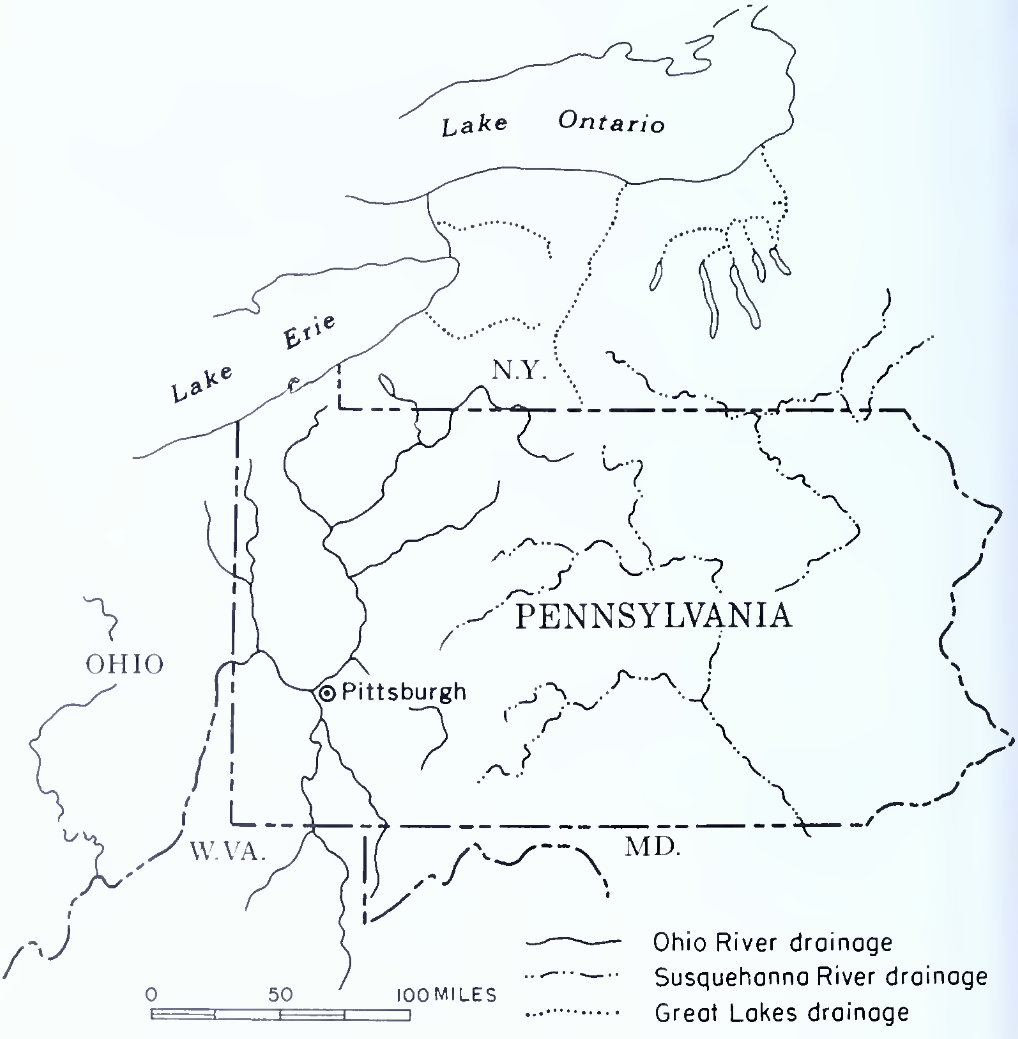


Figure 53. Drainage systems of western Pennsylvania.

of the Lake Erie drainage. An unusual situation exists in that the drainage from Lake Erie and Lake Ontario to the St. Lawrence River and the North Atlantic is a major drainage path yet the waters of the northwestern part of Pennsylvania eventually end in the Gulf of Mexico instead of in the North Atlantic. Only in western and northern New York State do major rivers flow into Lake Erie or Lake Ontario. In this chapter, we shall examine the reasons for this odd situation and how it has affected the Pittsburgh area.

In the early part of the Cenozoic Era (Figure 23), western Pennsylvania was probably a low, broad plain, gently but increasingly rolling to the east as it extended across the northeast-southwest trending folds which increase in intensity eastward. Across this surface the rivers flowed in broad meandering flat valleys so near their base level that they were widening rather than deepening their valleys. These rivers were mainly, but not completely, in the courses they now occupy. (Compare Figures 54a and 54b.)

Sometime in the late Cenozoic Era, the land was uplifted and the resulting rejuvenated streams cut deep valleys 300 to 400 feet below the upland surface. The resulting hills, obviously flat topped as seen from one of the hilltops or from the higher buildings in Pittsburgh, now have elevations of from about 1200 to 1400 feet above sea level, and are the remains of the old pre-uplifted erosion surface. Among the more prominent of these remnants are Squirrel Hill, the old Allegheny County Airport in West Mifflin, the Mount Lebanon-Dormont area, the highland portions of South Park, and an extensive area in east Wilkinsburg centering around the water tower near the intersection of the old William Penn Highway and the Greensburg Pike. Eventually, downcutting by the rivers slowed, and concurrently, sideward cutting increased, forming well-defined wide valley floors, the remnants of which now lie from 900 to 1000 feet above sea level. These flat areas are along or near the larger rivers and their major tributaries, at elevations about 200 to 300 feet above present stream levels.

These remnant valleys have been called the Parker Strath, from a typical occurrence near Parker, on the Allegheny River in northern Armstrong County, and from the Scottish word "strath" meaning a wide flat valley. The notable difference of the stream pattern of Parker Strath time from that of today was that the drainage was generally northward into the present St. Lawrence Basin rather than south and west into the Mississippi Valley. Figure 54a shows the river systems existing at that time in western Pennsylvania and neighboring states. The Monongahela flowed north to the present site of Pittsburgh, and thence again north along the present Ohio River channel to Beaver. At Beaver the Monon-

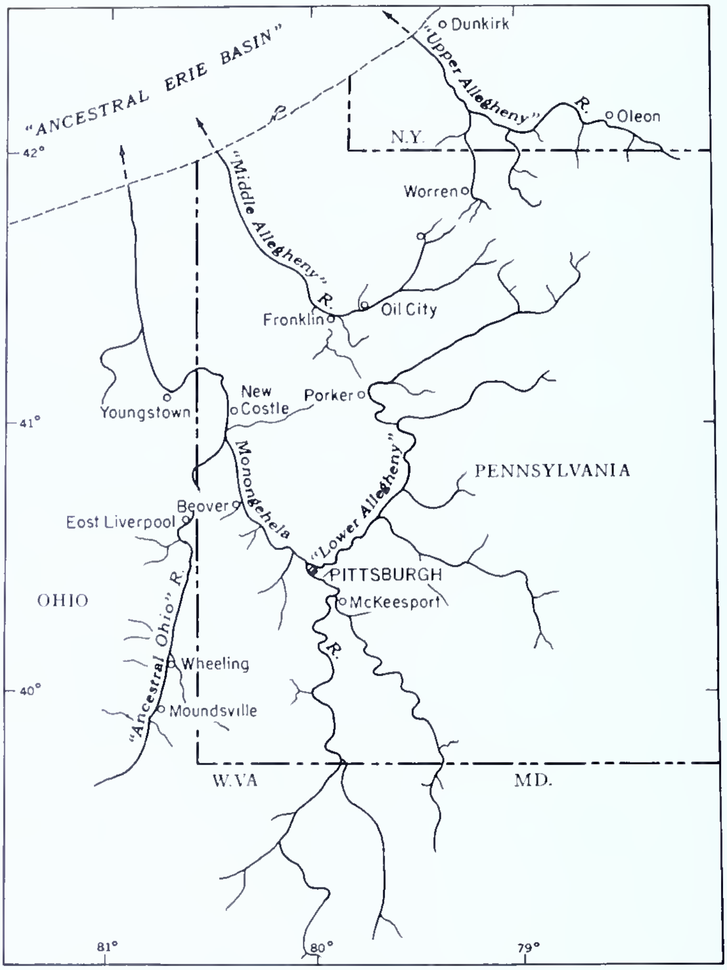


Figure 54a. Pre-glacial drainage of western Pennsylvania. Adapted from Leverett, 1934.

gahela continued north in the valley of the present Beaver River. It flowed past New Castle and Youngstown and finally into the Erie basin. The Ohio River between Moundsville and East Liverpool was at that time merely a tributary of the Monongahela and flowed north, entering the Monongahela just south of New Castle.

The present Allegheny River from Olean, New York to Pittsburgh was three separate rivers: a lower, middle, and upper Allegheny. The "Lower Allegheny" began at the Clarion River and flowed south to join the Monongahela at Pittsburgh. The "Middle Allegheny" course ran through the present Oil City and Franklin and then northwest along what is now French Creek to the "Ancestral Erie Basin." In New York state, the "Upper Allegheny" flowed through the present site of Olean and into the "Ancestral Erie Basin" just south of Dunkirk (Leverett, 1934; Shepps and others, 1959). These generally broad, flat-bottomed

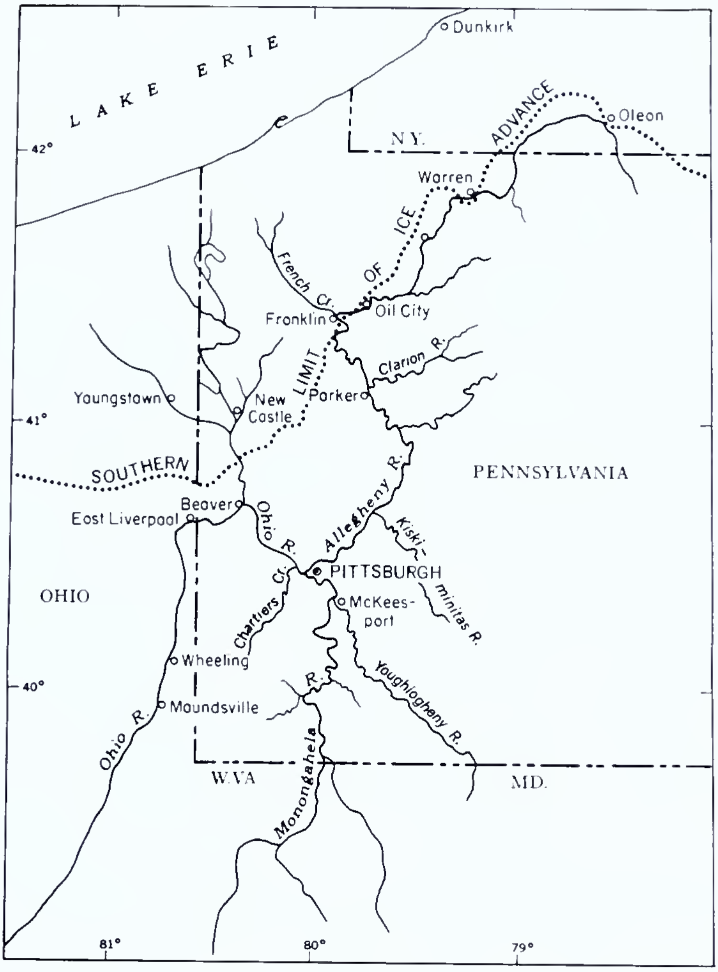


Figure 54b. Present drainage of western Pennsylvania. Limits of ice advance taken from Shepps et. al., 1959.

valleys persisted until the Pleistocene Epoch of the Cenozoic Era. The Pleistocene is familiarly called the Ice Age, since it is the time when the continental glaciers advanced over great parts of the northern hemisphere. (For a history of glaciation in Pennsylvania and an explanation of the topography which results from glacial action, the interested reader is referred to the booklet *Pennsylvania and the Ice Age,* published by the Pennsylvania Geological Survey as Education Series No. 6.)

Four major advances and retreats of the great ice sheets are recognized in many parts of the northern hemisphere, but of these only the last two advances, the Illinoian and the Wisconsin, reached the western Pennsylvania area, and neither of the two reached Pittsburgh. Pittsburgh's rivers, however, were drastically affected by the advent of the ice.

As the Illinoian glaciers advanced into northwestern Pennsylvania, the ice blocked the north-flowing streams and caused lakes to form at the edge of the glacier. Eventually, the lakes became so deep that the ancient Monongahela-Beaver drainage and the "Middle" and "Upper" Allegheny rivers were reversed. They have followed this southerly course to the present time.

Figure 54b shows the present courses of the main rivers of the Pittsburgh area. The Monongahela, after meeting its main tributary, the Youghiogheny, flows north to the "Point" at Pittsburgh, where it meets the south-flowing Allegheny River. The confluence of these two rivers forms the Ohio River which flows north to Beaver. At Beaver, the Ohio turns southwest to East Liverpool, Ohio, and thence south past Wheeling and Moundsville, West Virginia.

The ancient channels of the preglacial Monongahela can be traced by the position of linear bodies of unconsolidated sands, silts and gravels which are now stranded on rock shelves hundreds of feet above the present rivers. These alluvial deposits are called river terraces, and they can usually be identified on a topographic map by their flatness which contrasts with the adjacent hills of western Pennsylvania. Figure 55 shows the location of these old channels with respect to the present river position in the Pittsburgh area.

The river terraces mentioned above are actually resting on the remains of the old former valley floors—the Parker Strath level. During the Illinoian glaciation, the flow of the streams from the north was augmented by glacial meltwater. They were also heavily laden with silt, sand and gravel carried by the glacier from the largely igneous and metamorphic rocks of northern New York and eastern Canada. These streams swept down—or in many cases, against the previous direction of flow, thus "up,"—the ancestral Allegheny River (s) and ancestral (Lower) Monongahela. The floors of the wide, flat, rock-cut valleys consequently were covered with a thick blanket of glacial debris transported various distances as the carrying power of the streams changed. Raising the level of the ancestral Allegheny-Ohio system by deposition of this mass of alluvium ponded the undisturbed, still north-flowing streams which flowed into these rivers, notably the "Upper" Monongahela, the Youghiogheny, the Kiskiminetas, and Chartiers Creek. These streams in turn responded by building up their valley floors with layers of clay, silt, sand and some gravel derived from the sedimentary rocks of the surrounding Allegheny Plateau. This alluvial material is known as the Carmichaels Formation.

Along the Monongahela River, the terraces of the Parker Strath are plainly seen at Clairton, at Kennywood Park, in upper Homestead; as well as remnants at Versailles, Boston, above Coulter, and at other places on the Youghiogheny River. A very well-developed terrace at the level

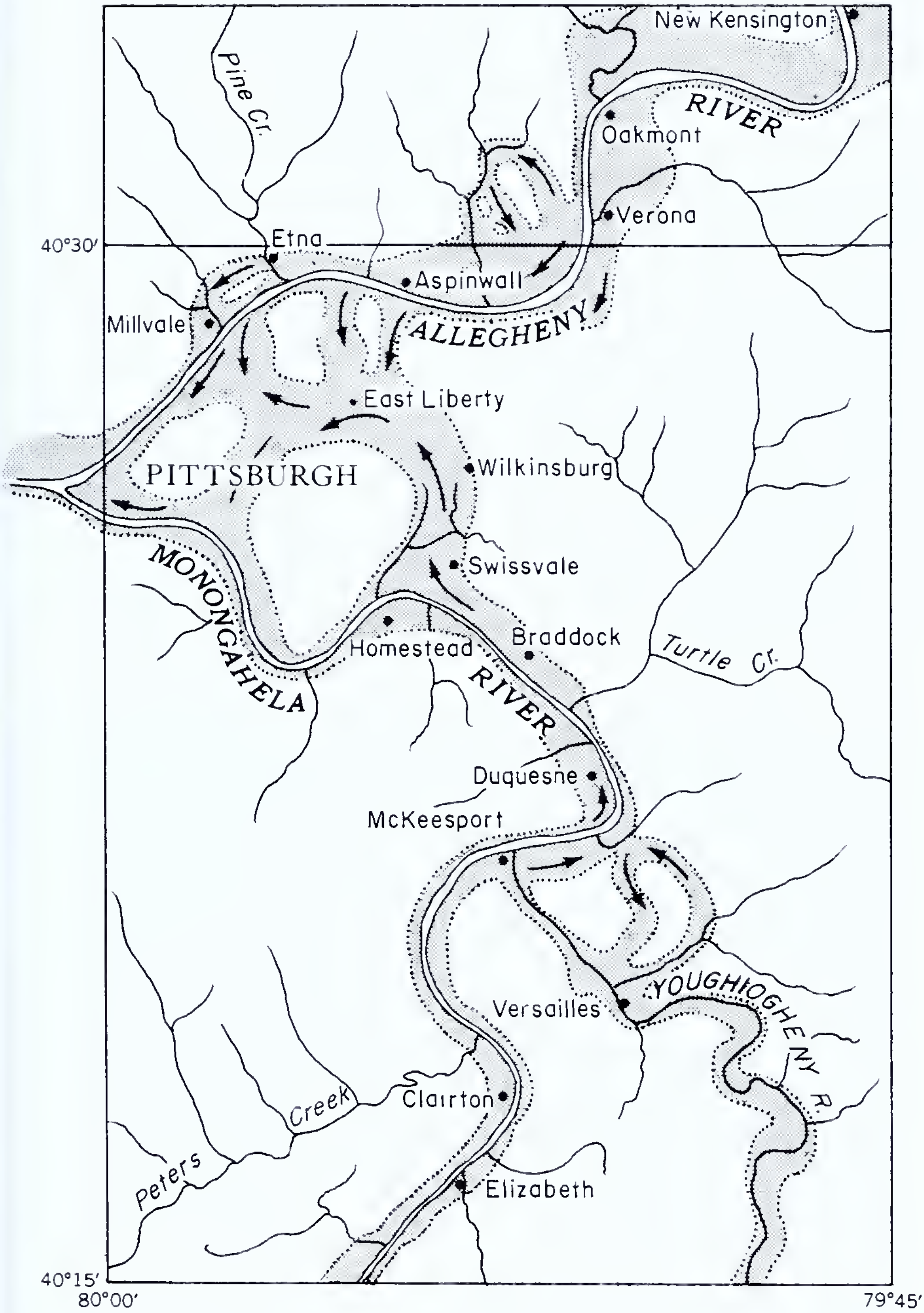


Figure 55. Old channels and high-level terraces on the lower ends of the Monongahela, Youghiogheny, and Allegheny valleys. Adapted from Leverett, 1934.

of the Parker Strath is located on the west bank of the Monongahela, at the Charleroi industrial park, about one-quarter mile southwest of the intersection of Interstate Route 70 and State Route 88.

Up the north bank of the Allegheny, terraces can be seen at Troy Hill, east of Millvale between Seavey Road and Friday Street, and in O'Hara Township, where the gravels exposed are shown in Figure 56. A large, well-developed terrace and gravel deposit is present in Harmar Township where the Pennsylvania Turnpike (Interstate Route 80) passes the Gulf Research Center. Several gravel pits and the route of the Bessemer and Lake Erie Railroad are also cut into this terrace (Locality 16). Farther north, Route 28, where it passes through Natrona Heights, crosses a well-developed terrace underlain by gravels 80 to 90 feet thick.

Along the Ohio, the terrace is wide on the north side of the river and is represented by Monument Hill, between Ridge and Reedsdale Streets on Pittsburgh's Northside, opposite Point Park, the area of Bellevue, which is chiefly built on it, parts of Avalon, Ben Avon, Emsworth, and the higher portion of many of the river towns downstream to Beaver and Rochester.

As the Illinoian glacier retreated, increased meltwater and possibly renewed uplift of the land rejuvenated the newly redirected streams.

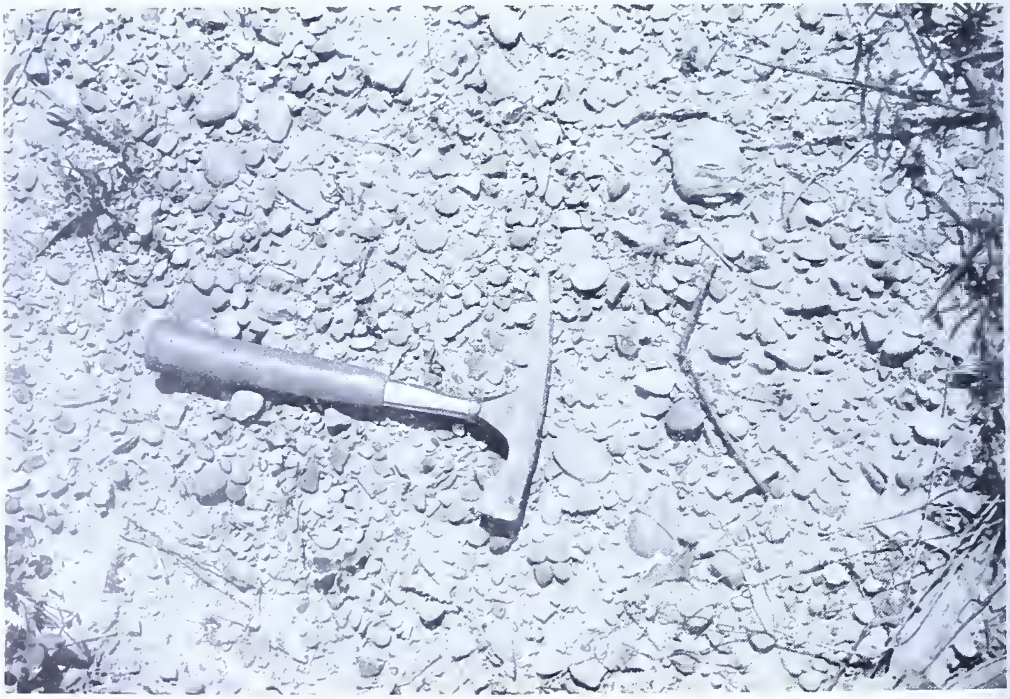


Figure 56. High terrace gravels of ancestral Allegheny River, O'Hara Township.

They cut their new channels far below the Parker Strath level, making permanent their glacially diverted courses and leaving the strath remnants perched high above the present river channels. At Pittsburgh, the rock floor of the strath lies about 900 feet above sea level—200 feet above river level—with the overlying glacial gravel or Carmichaels silt and sand having a thickness of 50 or more feet.

In cutting new channels below the Parker Strath, the streams locally took completely new courses, leaving behind great loops of channels and cut-off meanders which cross and recross the present valleys high above present stream level. Today these are wide valleys which are no longer occupied by a major stream.

These abandoned channels are a prominent topographic feature of the valleys of southwestern Pennsylvania and parts of Ohio, and seem confined to streams just south of the line of glaciation. Pittsburgh is fortunate, both geologically and geographically, in having a well-developed abandoned channel in the East End district (Plate 3 and Figure 55) where a mile-wide, flat valley leaves the Monongahela Valley at Rankin, passes through Swissvale, Edgewood and Wilkinsburg, is followed by Frankstown and Penn Avenues through Homewood-Brushton to East Liberty and Shadyside and thence passes through Oakland past the University of Pittsburgh back to the Monongahela River.

This feature, followed by the Pennsylvania Railroad main line and several of our principal east-west through streets, is the only direct natural overland route toward downtown Pittsburgh from the east. As a result, this comparatively narrow valley was urbanized far earlier than the Greenfield-Squirrel Hill-Hazelwood hill mass to the south or the hilly area between Allegheny Cemetery and Highland Park to the north.

Excavations made anywhere in this valley reveal layers of silt and sand, deposited by the "Old Monongahela," and in Oakland, excavations for the Cathedral of Learning and other large buildings exposed up to 40 feet of sand, gravel, sandstone, boulders, and layers of laminated plastic clay (Leighton, 1947).

Although this channel seems to have been primarily the work of the Old Monongahela, it extends into the lowland east of Highland Park along and above Washington Boulevard, west of Highland Park in Morningside, and in the Lawrenceville-Bloomfield-Allegheny Cemetery area. Some flow, in this area between the Old Monongahela and Allegheny Rivers, through low points in the divide, undoubtedly occurred. The lack of Allegheny type gravel in the Old Monongahela loop makes it evident that there was not a strong flow of Allegheny waters southward across the divide.

The cause, control and localization of these abandoned channels constitutes one of the major unsolved problems of Pittsburgh geology.

The continuing processes of downcutting, and increasingly, of lateral erosion by Pittsburgh's rivers excavated the rock bottom of their valleys to about 250 feet below the level of the Parker Strath, and to about their present cross-sectional profile. This is a broad, flat-bottomed U, with steep walls ascending to the level of the Parker Strath (see Figure 57, also 15 and 16).

Sometime subsequent to the establishment of this latest valley shape, the Wisconsin glacial invasion occurred. Again the ice field failed to reach the environs of Pittsburgh (see Figure 54b). This time, the drainage system was readily adjusted to the presence of the ice barrier to the north, and as a result, only very local changes occurred within the valleys. The glacial meltwaters again filled the Allegheny-Ohio valley bottoms with silt, sand, and gravel brought from the north. In the Pittsburgh area, this layer (the "Earlier Wisconsin gravel" of Figure 57) locally reached a thickness of 80 feet. Simultaneously, this alluvial ponding of the north-flowing streams emptying into the Allegheny-Ohio system again forced these streams to build up their bottoms with sediments derived from the hills to the south.

After the retreat of the Wisconsin glaciers, the volume of water and sediment coming down the rivers declined. The rivers cut new channels into, and locally reworked the Wisconsin valley-fill. The results are low terraces, including the modern floodplain, about 10 to 30 feet above present river level (the Later Wisconsin gravel and post-glacial alluvium of Figure 57).

Much alluvium brought down river by the Allegheny and Monongahela during Wisconsin time, was dumped at their confluence. This deposit, its margins continuously nibbled away and built up here and there by both rivers, is built westward from Grants Hill, the high ground now the site of Mellon Square and the City-County complex. This gravel deposit is, of course, now the low, flat area of the Triangle, the heart of downtown Pittsburgh.

The other low terraces are at present occupied by many of Pittsburgh's industrial plants, notably Jones and Laughlin Steel's Pittsburgh works along both banks of the Monongahela.

The porous Wisconsin gravelly alluvium which underlies the Allegheny and Ohio valleys and the Triangle (see Figure 57) is the primary source of ground water in Allegheny County. This water supply has been erroneously miscalled "Pittsburgh's Underground River" because it is not at all an isolated body of water separate from the rivers above it.

VIII SOILS AND LANDSLIDES

ALLEGHENY COUNTY SOILS

by

David J. Belz

U. S. Department of Agriculture, Soil Conservation Service

The soil scientist defines soil as the collection of natural bodies occupying portions of the earth's surface that support plants, and that have properties due to the integrated effect of climate and living matter, acting upon parent material, as conditioned by relief, over periods of time (Soil Survey Manual, 1951). Soils are classified and given geographic names from the localities where they are typically developed. Many of the soils of Allegheny County are formed in place, usually on uplands, on residual parent material resulting from weathering of the underlying rock; these are the residual soils which are closely related to the characteristics of the underlying rock. Other soils are developed on colluvium, rock material moved downhill by gravity and flowing water and accumulated at the base of upland slopes and ridges; these are colluvial soils. Some other soils in Allegheny County are formed on alluvial parent material deposited by streams; these are alluvial terrace or flood plain soils.

There is a mutual variability between geology and soils. As the geologic material varies, the characteristics of the associated soil usually vary. This variability produces approximately 1,100 different soils in the northeastern states. With such a large number of soils, there is a need for a systematic means of studying and grouping them. This need is fulfilled by a system of soil classification.

One of the major applications of soil study and classification is the interpretation and prediction of soil behavior. We need to be able to make accurate predictions of the problems to be encountered when a soil is turned to both agricultural and non-agricultural uses. Soils have limitations to their use, and in making soil interpretations the soils are rated in terms of the degree of limitation—slight, moderate or severe—for the particular use.

Soil interpretations are useful for preliminary evaluation, comparison and selection of construction sites. They enable the user to determine both the type and degree of soil problems likely to be encountered. They also aid in determining the type and intensity of on-site investigation required so that it can be made at minimum cost.

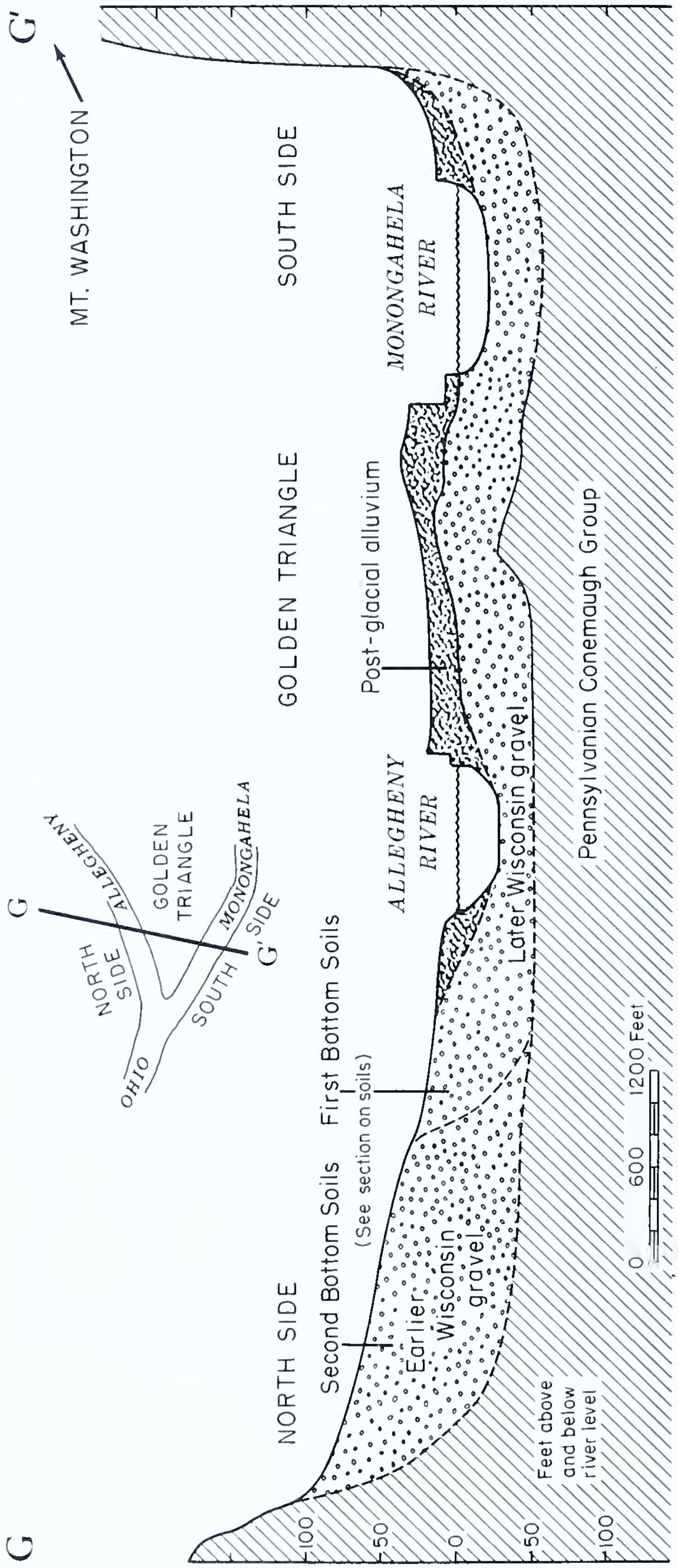


Figure 57. Section across downtown Pittsburgh showing broad U-shaped rock floor and the relations among the overlying unconsolidated valley-fill deposits.

Soil interpretations can be used by local government officials and others engaged in land-use planning. Well planned land use matches soil limitations to the requirements of the particular land use in question. With properly planned land use, many problems can be avoided which result from misuse of the soil.

A general presentation of soils information can be made on a small scale map by using soil associations. These associations are groups of soils which ordinarily occur together in the landscape. A soil can occur in more than one association. Figure 58 shows the soil associations of Allegheny County and the names of the main individual soils occurring within each association.

Residual Soils

The Guernsey, Westmoreland and Library soils are the predominant residual soils in the area underlain by the Permian age Dunkard Group and the Pennsylvanian age Monongahela Group. All are relatively nonacid soils because they are derived from parent material containing carbonates. The main residual soils associated with the Pennsylvanian Conemaugh and Allegheny Groups are the Gilpin, Weikert, Wharton, and Vandergrift soils. All of these are relatively acid because of abundance of shale and relative lack of carbonate. Note the similarity in distribution between the residual soil associations and the location of the geologic groups shown on Plate 1, Figure B.

Table 2 summarizes the characteristics of the individual residual soils. Each soil has three layers which from the surface down are the surface soil, the subsoil, and the substratum. Despite differences in the local soils, the surface soil, the upper 8 to 10 inches, is usually a grayish-brown granular silt loam. The large proportion of organic matter in this layer and the years of plowing and other disturbing factors such as burrowing animals have made the surface soil similar throughout the county. The subsoil, however, varies as noted in the table. The substratum, which is the layer of unconsolidated or weathered material little affected by organic activity, is also described.

Figure 59 is a triangular diagram which defines the texture of a soil in percentages of sand, silt, and clay. For instance, soil containing ⅓ sand, ⅓ silt, and ⅓ clay lies at the center of the triangle and is called a clay loam. The four most common textures of Allegheny County soils are: silt loam, silty clay loam, silty clay, and loam. These are terms used to describe the surface soil, the subsoil and the substratum. The table and the triangular diagram may be used jointly as in the following example. In the table the substratum of the Westmoreland

Table 2. *Principal Residual Soils of Allegheny County*

Underlying Geologic Units	*Soil*	*Drainage*	*Permea-bility*	*Depth to Water Table*	*Subsoil*	*Substratum*	*Parent Material*	*Depth to Parent Material*
DUNKARD AND MONONGAHELA GROUPS	Westmoreland	Well drained	Moderate	Below 4 feet	Yellow brown blocky shaly silt loam to silty clay loam.	Yellow brown shaly silt loam.	Interbedded shale, fine grained sandstone and limestone.	36 inches
	Guernsey	Moderately well drained	Slow	Between ½ to 3 feet	Brown blocky silty clay loam to silty clay.	Grayish brown massive silty clay loam to silty clay, mottled with yellowish brown.	Interbedded shale, siltstone and limestone.	60 inches
	Library	Somewhat poorly drained	Slow	Within 1 foot during wet seasons	Olive brown blocky silty clay to clay, mottled with yellowish brown.	Gray massive silty clay loam to silty clay, mottled with yellowish brown.	Thin-bedded limestone and shale.	45 inches
CONEMAUGH AND ALLEGHENY GROUPS	Gilpin	Well drained	Moderate	Below 4 feet	Yellowish brown, blocky, shaly, silty clay loam.	Yellowish brown shaly silt loam with relict bedding.	Shale and some fine-grained sandstone.	34 inches
	Weikert	Well drained	Moderately rapid	Below 4 feet	Yellowish brown, blocky very shaly silt loam.	Weathered shale and fine-grained sandstone.	Shale and fine-grained sandstone.	15 inches
	Wharton	Moderately well drained	Slow	Between 1½ to 3 feet	Yellowish brown blocky silty clay loam to silty clay, mottled with gray in lower part.	Olive brown massive silt loam to silty clay loam, mottled with gray.	Gray clay shale.	50 inches
	Vandergrift	Moderately well drained	Slow	Between 1½ to 3 feet	Reddish brown blocky clay.	Reddish brown massive clay, commonly mottled with gray.	Red weakly calcareous claystone to shale.	60 inches

soil is a silt loam and according to the diagram a silt loam may contain 50 to 88 percent silt, 12 to 27 percent clay, and 0-38 percent sand, or it may contain 50 to 80 percent silt, 0 to 12 percent clay, and 8 to 50 percent sand.

Drainage refers to the rate and extent of removal of water from the soil whereas permeability is a measure of flow in inches per hour of

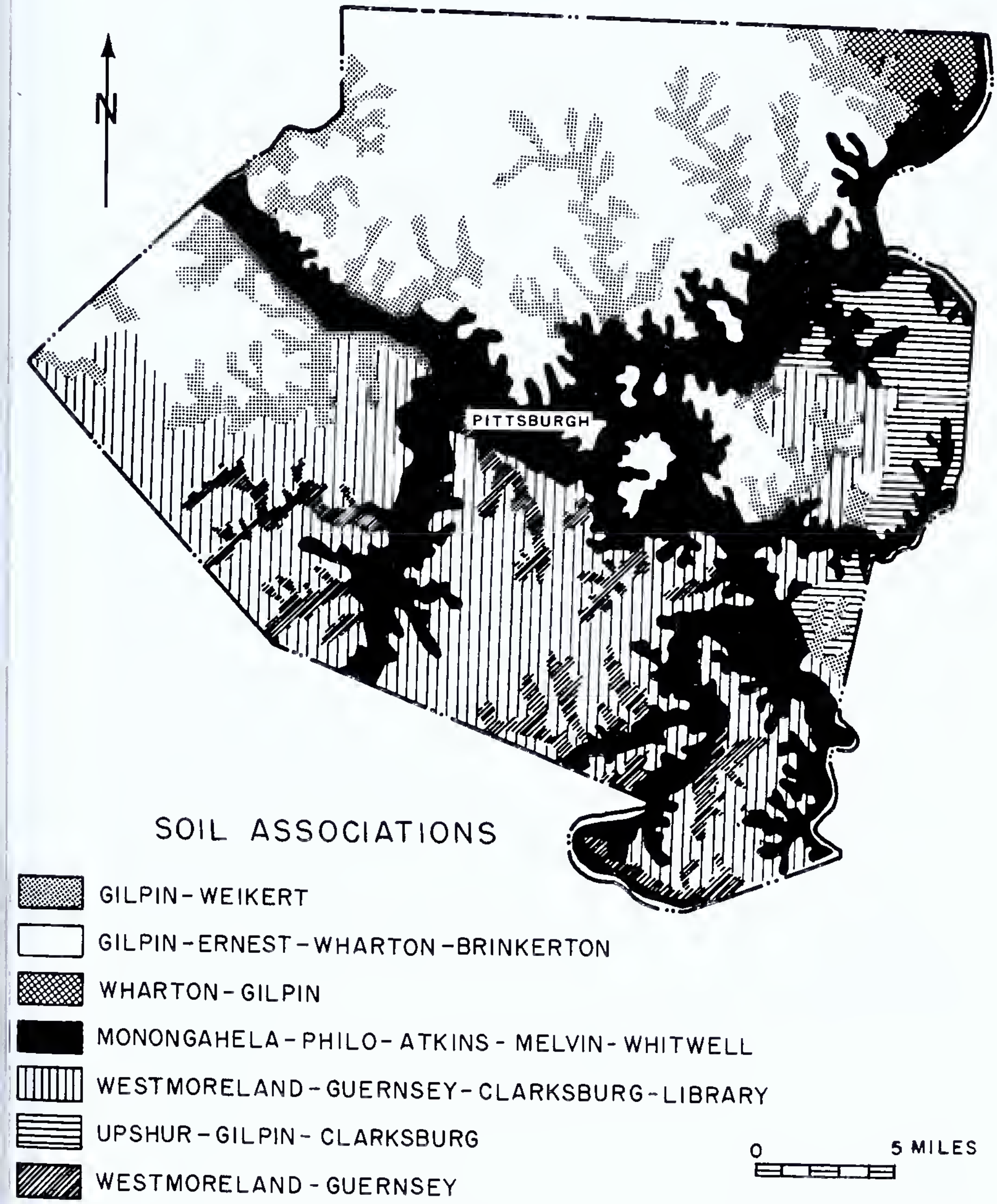

N
PITTSBURGH
SOIL ASSOCIATIONS
GILPIN-WEIKERT
GILPIN-ERNEST-WHARTON-BRINKERTON
WHARTON-GILPIN
MONONGAHELA-PHILO-ATKINS-MELVIN-WHITWELL
WESTMORELAND-GUERNSEY-CLARKSBURG-LIBRARY
UPSHUR-GILPIN-CLARKSBURG
WESTMORELAND-GUERNSEY
0
5 MILES

Figure 58. Soil associations, Allegheny County. Adapted from Allegheny County soil and water conservation district program, 1967.

water through a unit cross-section of saturated soil. Slow permeability is .05 to 0.2 inches per hour, moderate flow is 0.8 to 2.5 inches per hour.

The two dominant "problem" soils of the Pittsburgh area are the Guernsey, where it is developed on Monongahela Group rocks on steeper slopes in the Mount Lebanon-South Hills area, and the Vandergrift, formed on the Conemaugh red claystones on a variety of slopes. The Guernsey soil is easily eroded, tends to rapid water logging because of slow permeability, and when in this condition is unstable and subject to sliding. The Vandergrift soil is developed on a weak rock; is easily eroded, and tends to very rapid water logging because of slow downward water movement through it. It contains a plastic clay which is very prone

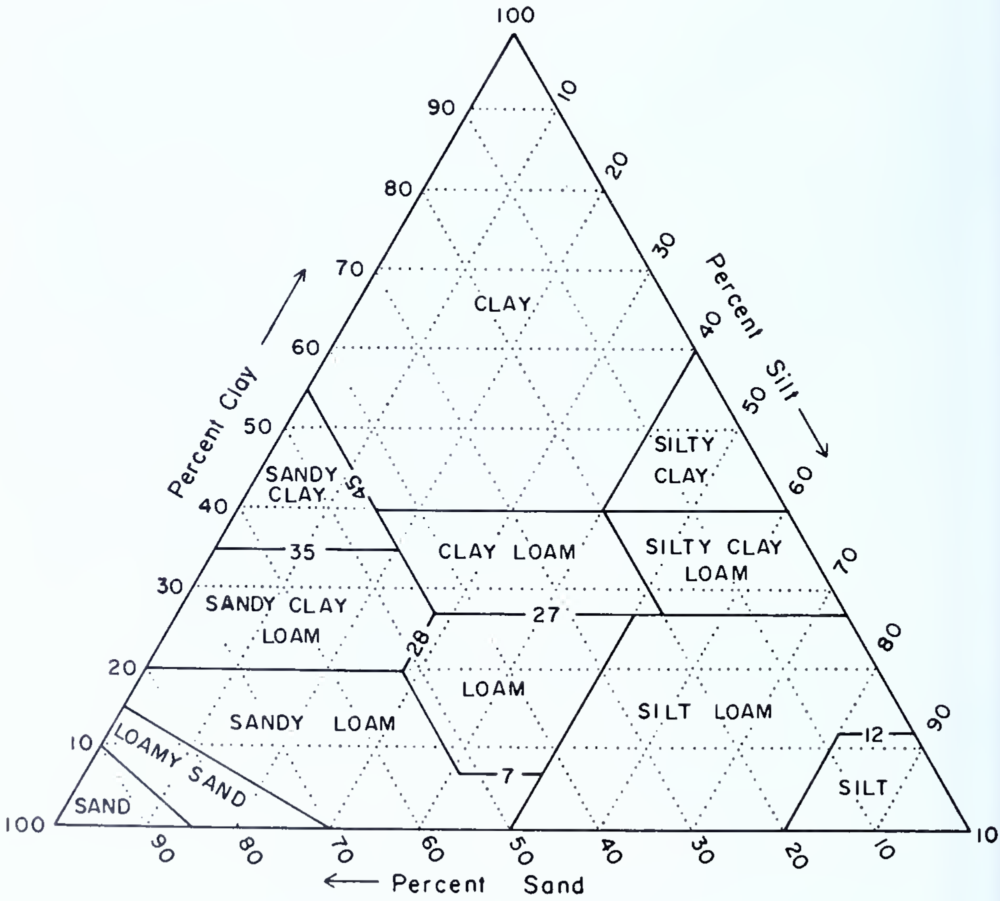


Figure 59. Standard U. S. Department of Agriculture soil texture classes in percentages of clay (particles below 0.002 mm), silt (particles between 0.002 mm and 0.05 mm), and sand (particles between 0.05 mm and 2.0 mm). Adapted from Soil Survey Manual, 1951, p. 209.

to swell when wet and shrink when dried. The easily saturated condition and plastic clay content make the Vandergrift soil subject to sliding.

Colluvial Soils

All the soils described in association with the geologic groups are upland soils developed from residual parent material. At the base of the slopes, colluvial material has accumulated and colluvial soils have developed. The properties of the colluvial soils are thus related to the character of the associated uplands. The colluvial soils associated with uplands having a predominance of limestone are the Clarksburg soils, which are relatively non-acid. The colluvial soils associated with uplands containing dominantly acidic material, mostly shale and sandstone, are the Ernest and Brinkerton soils. All three soils are up to 60 inches deep (see Table 3).

The colluvial soils have a fragipan which is a type of hard pan. It is a dense, brittle, platy, slowly permeable layer, rich in silt, sand, or both, and usually relatively low in clay. It occurs 15 to 40 inches below the surface and may vary in thickness from a few inches to several feet. It commonly interferes with water percolation and root penetration, and thus can be a problem in the location of septic tank disposal fields and in landscaping. When dry, the layer appears indurated, but this apparent induration disappears on moistening. The origin of the fragipan is as yet not well understood.

Alluvial Soils

Some soils are formed on alluvial parent material, that material deposited by streams. These Allegheny County soils are separated in upward sequence into three topographic positions—first bottom, second bottom, and terrace.

The soils of the first bottom occur on low lying, nearly level floodplains, subject to frequent flooding (the later Wisconsin gravels of Figure 57, Section VII). Textural variation in these first bottom soils is essentially due to stratification of the alluvial material, and not to soil formation processes.

The soils of the second bottom occur on the higher, nearly level floodplains and are seldom subject to flooding (the earlier Wisconsin gravels of Figure 57, Section VII). They have an increase in clay content downward through the soil profile, which is weakly developed.

The soils of the terrace position are the oldest alluvial soils, developed on the alluvium deposited during the Pleistocene Epoch on the Parker

Table 3. *Principal Colluvial Soils of Allegheny County*

Soil	*Drainage*	*Permeability*	*Depth to Water Table*	*Subsoil*	*Fragipan*	*Substratum*	*Character of Uplands*
Clarksburg	Moderately well to somewhat poorly drained	Slow	Between 1½ to 3 feet	Yellowish brown blocky silty clay loam to clay loam, mottled with grayish brown.	Yellowish brown platy silty clay loam to clay loam mottled with brownish gray.	Yellowish brown massive silty clay loam to clay loam mottled with brownish gray.	Mixed limestone and shale
Ernest	Moderately well to somewhat poorly drained	Moderately slow	Between 1½ to 3 feet	Yellowish brown blocky silt loam to silty clay loam, mottled with grayish brown.	Yellowish brown platy silty clay loam to gravelly silt loam mottled with grayish brown.	Brown massive silty clay loam to gravelly silt loam mottled with brownish gray.	Shales and sandstone
Brinkerton	Poorly drained	Slow	At/near surface during wet seasons	Gray blocky silt loam to silty clay loam mottled with brown.	Gray platy silty clay loam mottled with brown.	Gray massive silty clay loam mottled with brown.	Shales and sandstone

Table 4. Principal Alluvial Soils of Allegheny County

Position	Soil	Drainage	Permeability	Depth to Water Table	Flooding	Acidity	Subsoil	Substratum	Thickness of Subsoil
FIRST BOTTOM	Philo	Moderately well to somewhat poorly drained	Moderate	Between 1½ to 3 feet	Occasional	Relatively acid	Brown blocky loam to silty clay loam, mottled with grayish brown.	Brown stratified silt, sand and clay, mottled with grayish brown.	12 to 36 inches
	Atkins	Poorly drained	Moderate	At/slightly beneath surface in wet seasons	Occasional to frequent	Relatively acid	Grayish brown blocky silty clay loam to silt loam, mottled with yellowish brown.	Brownish gray stratified sand, silt, clay and gravel, mottled with yellowish brown.	10 to 36 inches
	Melvin	Poorly drained	Moderately slow	At/near surface in wet seasons	Occasional to frequent	Relatively non-acid	Grayish brown blocky silty clay loam, mottled with yellowish brown.	Olive gray stratified sand and clay, mottled with yellowish brown	10 to 36 inches
SECOND BOTTOM	Whitwell	Moderately well to somewhat poorly drained	Moderately slow	Between 1 to 3 feet	Seldom	Relatively acid	Brown to reddish brown blocky silty clay loam to sandy clay loam, mottled with grayish brown.	Reddish brown stratified silt, clay & sand, mottled with grayish brown.	12 to 40 inches
TERRACE	Monongahela	Moderately well drained	Moderately slow	Between 1½ to 3 feet	None	Relatively acid	Yellowish brown blocky loam to clay loam, mottled with yellowish brown in lower part.	Yellowish brown platy loam to clay loam fragipan about 16 inches thick, mottled with brownish gray, lying on yellowish brown stratified silt, sand and gravel, mottled with grayish brown.	10 to 24 inches

Table 5. *Artificial Land Types*

Locale	*Land Type*	*Composition*	*Origin*	*Acidity*	*Slope (percent)*
Bottom lands	Land Fill	Shale, sandstone, limestone, brick, cinders, industrial waste and junk mixed with upland soil materials.	Disposal of excavated material, refuse, sanitary land fill.	variable	
	Mine Wash	Coal and earthy material	Coal mine drainage, coal washing plants.	Very acid	
Mixed, Dominantly Bottom lands	Slag Dumps (commonly very steep sided mounds)	Industrial slag	Blast furnaces & steel mills	Relatively non-acid	0-75
Terraces	Made Land, Alluvial	Highly mixed water deposited materials	Extensive earth-moving operations except strip-mining		0-25
Uplands	Made Land, Heavy Textured, Acid	Mixed clayey soil material	Ditto	Relatively acid	0-75
	Made Land, Heavy Textured, Calcareous	Mixed clayey and calcareous soil material	Ditto	Relatively non-acid	0-75
	Made Land, Medium Textured	Mixed shale soil material	Ditto	Relatively acid	0-75
Mixed, Dominantly Uplands	Strip Mines	Mixed rock, waste coal and soil material	Coal or clay strip-mining	Acid to very acid	0-75
Mixed	Mine Dumps (commonly very steep sided mounds)	Mixed waste coal, shale, sandstone and other earth materials.	Deep mining operations	Acid to very acid	0-75

Strath, at about 900 feet elevation. They show a marked increase in clay downward through the profile, which is strongly developed (see Table 4).

Most of the alluvial soils are found in the major river valleys of Allegheny County (see the black pattern on Figure 58, the soil association map).

Artificial Land Types

An additional category, "artificial land," is found in this area. These strictly speaking are not soils, but occur in sufficient quantity in Allegheny County to justify some comment, although they are usually so variable in properties as to defy much classification (Table 5).

LANDSLIDES

by

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A landslide is the downward and outward movement of slope-forming materials composed of rock, soils, artificial fills or combinations of these materials. Although there are only three basic types of landslides, namely falls, slides and flows, geologists and engineers recognize many subtypes. In western Pennsylvania only three types of movements are common however. These are slumps, slow earth flows in soil, and rockfalls.

The relatively flat-lying sedimentary rocks of western Pennsylvania, which consist predominantly of silty shales and claystones, weather to a silty clay containing fragments of sandstone or limestone. Except for alluvial and colluvial deposits, which occur mainly in the larger stream valleys, residual soil blankets the area. The residual soil cover usually ranges from 5 to 15 feet in thickness and grades downward into partially decomposed rock* Although these soils are generally stiff, they creep down even the gentlest slopes under the influence of gravity, usually at an almost imperceptible rate. Most of the movement occurs in the spring of the year when the soil is saturated with water. Major slides in this material are almost non-existent under natural conditions but disturbances by man, such as excavating into a slope or loading a slope by placing fill on it often result in large movements. For example, in Stowe Township, near McKees Rocks, an 8 foot cut made in colluvial material at the base of a slope triggered a slide about 500 feet wide and several hundred feet long (Philbrick, 1959). This resulted in the total destruction of six homes and damage to several others as well as dislocation of a highway, a streetcar line, and overhead and underground utilities.

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* Soil is defined differently by the soil scientist and the engineering geologist. To the soil scientist a soil must be able to potentially support rooted plants; to the engineering geologist soil is the layer or mantle of loose rock material that forms the surface of the land and rests on hard rock which is difficult to excavate. In Allegheny County "soil" to the engineering geologist is much thicker than the "soil" of the soil scientist.

Excavation at the base of the slope in Figure 60 near Mt. Nebo resulted in the sliding of large blocks along joint planes.

The interbedded nature of the rocks in the area also results in small but often dangerous rockfalls. Cuts containing either hard sandstone or

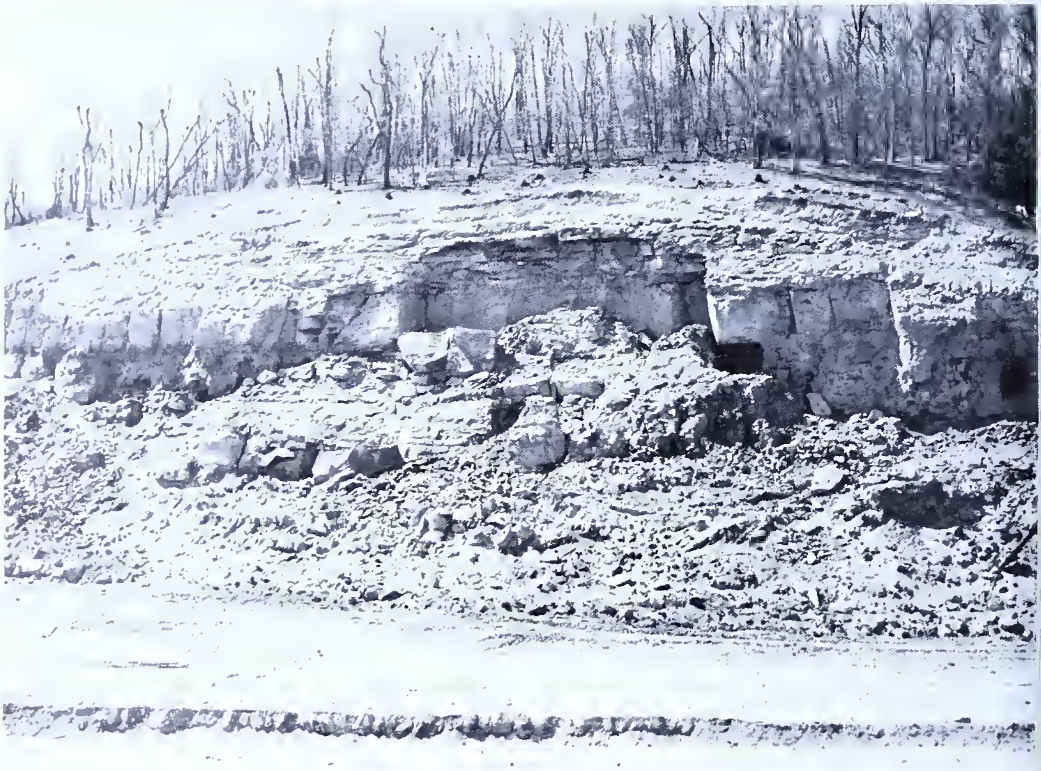

Figure 60. Sliding of large blocks along joint planes near Mt. Nebo. Sliding caused by excavation at base of slope during construction of Interstate Route 279.

limestone seams and underlain by relatively weak shales or claystones are common throughout western Pennsylvania. Weathering produces relatively rapid decomposition and spalling of the softer rocks so that eventually unsupported ledges of limestone or sandstone result. In time weathering progresses to the point where the rock can no longer sustain the stress developed by its overhanging weight and the ledge falls. A striking example of this is the cut on the Penn Lincoln Parkway immediately west of the Bates Street exit (Locality 37). Here the Ames limestone, one to two feet thick and approximately 20 feet above road level, is underlain by a relatively weak red claystone of the Pittsburgh red beds. Spalling of the claystone and subsequent falls of the undercut limestone frequently prevented use of the inside lane of the road from the time of the completion of the Parkway in 1955 until 1963 when a barrier was constructed to prevent the falling limestone blocks from reaching the roadway.

IX ECONOMIC GEOLOGY

INTRODUCTION

by

Louis Heyman

Pennsylvania Geological Survey

Economic geology is the application of the science of geology to the discovery, evaluation, extraction, beneficiation and use of mineral materials having commercial value. In the Pittsburgh area, the important "mineral materials having commercial value" are at present, coal, oil and gas, sand and gravel, rock suitable for concrete aggregate and crushed rock, surface and ground water, and clay. Of these, the fossil fuels: coal, oil and gas have been most important for the economic development of the Pittsburgh area. This is true not only for the intrinsic value of the fuels themselves, but also for those major industries which these fuels have drawn to the area, namely iron and steel, glass, and in former days, salt. These basic industries in turn support other raw material and by-product industries. As examples, the iron and steel industry requires limestone for flux and sand and clay for molding and refractories. By-product industries process the chemicals recovered during the making of coke for iron smelting; they also use blast-furnace slag in the manufacture of cement, building block, aggregate, and railroad ballast.

Some historical background of the development of the coal industry in Allegheny County and vicinity (taken in part from Eavenson, 1942) illustrates how strongly this resource influenced the early growth of the region.

The presence of coal, probably the outcrop of the Upper Freeport seam along the Kiskiminetas River a few miles below the present town of Saltsburg, Indiana County, was noted on a map made in 1752. Coal, now known as the Pittsburgh seam, was recognized near the mouth of Redstone Creek in the vicinity of present-day Brownsville, Fayette County, in 1754.

In the Pittsburgh area, coal cropping out along Saw Mill Run, on the south side of Coal Hill (now Mount Washington) was noted in 1759, and probably mined on a small scale by 1761.

The earliest record on a map of the Pittsburgh seam and a mine in it, is on a *Plan of Fort Pitt and Parts Adjacent*, dated 1761. The mine, probably the first systematically operated west of the Allegheny Mountains, was named Ward's Pit for Major Edward Ward, who opened it. It was at first worked by British troops to obtain fuel for Fort Pitt, which it overlooked, being located on the north side of Mount Washington just across the Monongahela from the Point.

By 1790, numerous mines had been opened in the Pittsburgh seam. A brewery at the Point was supplied with coal from Schenley Heights as early as 1795. By 1832, the daily consumption of coal in Pittsburgh was 400 tons, of which a large portion undoubtedly came from Minersville, now part of Schenley Heights (see Plate 3).

Although a record of an accident in 1789 to a coal-laden keelboat on the Monongahela is the earliest record of coal shipment by water, by January 1793, two tons of coal shipped by keelboat to Fort Washington (now Cincinnati) was reported in a routine way. In 1814, the first shipment of coal by flatboat was made when 200 tons of coal from Coal Hill was shipped to Louisville, Kentucky in two boats, and by 1816, coal was being shipped regularly by steamboat.

In 1797, the first glass factory west of the Alleghenies was started near the Point, fueled with coal from Ward's Pit. An 1833 listing of industrial establishments in Pittsburgh shows four glass plants consuming 840 tons of coal per year (about two tons per day). By 1836-37, a table of all factories on the south side of the Monongahela included nine glass factories consuming 6400 tons of coal per year (about 17½ tons per day).

Brine from which salt was obtained was at first recovered from springs, then from dug pits and finally from bored wells. The earliest brine wells were drilled to a depth of about 60 feet on Kanawha River near Charleston, West Virginia, between 1806 and 1808. In 1809, salt from brine obtained from a spring and using local coal as a fuel was produced on Connoquenessing Creek near Butler.

Tarentum was one of the first places in western Pennsylvania where salt was produced from brine. Before 1810, several wells were completed and others were being drilled. Both sides of the Allegheny were soon lined with brine wells. A good brine well was drilled on the bank of Kiskiminetas River in 1813 initiating a large salt industry centered at Tarentum and extending along Allegheny and Kiskiminetas Rivers, mainly using the Upper Freeport coal as fuel.

Most of the brine came from the Second Salt or "Sixty Foot" sand at an average depth of 400 feet below the Upper Freeport coal, which is at or near the surface in this area. This sand is in the Pottsville Group, the basal group of the Pennsylvanian age rocks. Some of the wells may have penetrated and produced brine from the deeper Maxton sand at the base of the Pennsylvanian System or the Big Injun sand in the upper part of the Mississippian System. All these sands produce oil and gas elsewhere, and the earliest traces of petroleum detected in this area, aside from surface seeps, were noticed with the brines from these wells. Most of the drillers of the early oil wells, including Uncle Billy Smith from Tarentum who drilled for Colonel Drake, were originally salt well drillers.

From 1815 to 1870, the salt industry was one of great importance west of the mountains, and it was the first major user of coal. In the period 1820-1835, more coal was used for extracting salt from brine in western Pennsylvania than for any other single purpose. In 1833, two salt works at Pittsburgh used 7200 tons of coal yearly, while the Pennsylvania Senate Journal for 1833-1834 estimates that 90 salt plants in the western part of the state used 200,000 tons of coal annually.

Coke is a spongy residue created by using heat to drive off the volatile constituents of bituminous coal in an oxygen-deficient environment. The fixed carbon and ash of the coal are fused together, forming a material strong enough to support the burden of the ore and limestone flux in a blast-furnace, while permeable enough to permit free passage of the air blast through the burning mass during smelting. This generates the high temperature and carbon monoxide needed to free iron of the oxygen combined with it in the ore.

The first blast-furnace in the Pittsburgh area was started in 1794 in the Shadyside district of the city, where a historical marker on Bayard Street, near Amberson Avenue, marks the approximate location. Operating on charcoal, it soon ran out of ore and fuel, and was never successful. Coke was made and used in smelting iron at least as early as 1818 at the Plumpsock Foundry between Connellsville and Brownsville in Fayette County, but the first oven for coking Pittsburgh coal was not erected until 1833, in Connellsville. The real start in the use of coke as a blast-furnace fuel began November 16, 1859, when the Clinton Furnace in Pittsburgh was started, using Connellsville coke as fuel. This was the first furnace in the county since the failure of the Shadyside venture, and its success set off a phenomenal growth in iron making and the use of coke. Soon the iron industry in this section of the country depended almost solely on coke made from the Pittsburgh coal.

In 1841 no coal was coked in the Pittsburgh area, and in the entire Pittsburgh seam area of Pennsylvania only 100 tons were coked. By 1855, in the Pittsburgh area, 40,000 tons were coked, and in the total Pittsburgh seam area of Pennsylvania 55,000 tons were coked. In 1880, 194,393 tons of coal were coked in the Pittsburgh area, while 4,262,000 tons were used for coke in the entire Pennsylvania Pittsburgh coal area. Another measure of the growth of the coal and steel industry is that in 1880, in the Connellsville district alone, 3,368,000 tons of coal, probably all from the Pittsburgh seam, were coked, out of a total of 5,238,000 tons coked in the entire United States.

COAL

by

Louis Heyman
Pennsylvania Geological Survey

Several bituminous coals of economic importance underlie the area considered in this report. Particularly significant are the Redstone and Pittsburgh coals of the Monongahela Group and the Upper Freeport coal of the Allegheny Group.

In the northern part of Allegheny County around Bakerstown, the Bakerstown coal of the Conemaugh Group, normally a poor quality coal only about a foot thick, thickens erratically up to 30 inches locally, and has been obtained from several small mines in that area.

The Waynesburg coal of the Dunkard Group (Locality 31) and the Sewickley coal of the Monongahela Group (the coal at the base of the Benwood in Figure 25), are usually thin and dirty, but have been mined locally for domestic use.

In the Allegheny Group the coals of the Kittanning Formation, which lies directly below the Freeport Formation are deep under cover everywhere in the county. For instance, at Mt. Washington, they are probably at a level of 230 to 255 feet above sea level, which is 450 to 480 feet below the level of the Monongahela River. They are known only from drill holes in the New Kensington 15-minute quadrangle, roughly the northeast part of the county. An estimate made in 1953 of recoverable reserves over 28 inches thick gives 11,826,000 tons for the Kittanning coals in the limited area of the county where data is available. These seams constitute reserves which will probably remain untouched, because of their depth and comparative thinness, until the prime coal reserves in the area have been exhausted.

From the standpoint of present and past production and recoverable reserves, there are two beds of major importance in this area, the Pittsburgh and Upper Freeport seams, and one of lesser importance, the Redstone coal. All these coals are of high volatile bituminous rank, and the Upper Freeport and Pittsburgh coals are excellent coking coals.

The Redstone is the uppermost coal of the three, and occurs about 50 feet above the Pittsburgh seam. It is of good quality in the southern part of the county where it is mined, but is extremely irregular, ranging from a few inches to 60 inches thick. The general range of thickness in the minable areas is 29 to 50 inches. An estimate made in 1953 of recoverable reserves over 28 inches thick gave 54,039,000 tons of Redstone coal in Allegheny County.

The Pittsburgh coal is one of the world's major economic resources, and is probably the best known, as it is certainly the most valuable, of all the bituminous coal beds of the Appalachian region. It is uniformly present, of constant thickness and high quality, and is suitable for almost every use, but is especially valuable for coking.

From 1759 to 1804, the total bituminous coal output of Pennsylvania was derived from this seam, and until 1940, it usually supplied over half. In 1956, the Pittsburgh seam contributed 40 percent of Pennsylvania's bituminous production, and 7 percent of the total U. S. production.

Generally, the seam consists of a roof coal and a main coal, separated by a claystone parting up to 3 feet thick (see Figure 13). The upper, or roof coal is high in ash, and is usually left in the mine to prevent slacking of the overlying weak shales. The lower coal ranges from 42 to 108 inches thick, averaging about 66 inches, and is subdivided into four distinct benches. From top to bottom, these are the upper or "breast", about 48 inches of good coal; the bearing-in, about 4 inches of soft crumbly coal; the brick bench, up to 36 inches of excellent blocky coal; and the bottom coal which is thin and dirty and is usually left in the mine (Johnson, 1929; Shaw and Munn, 1911).

The Pittsburgh seam is the basal unit of the Monongahela Group; its extent is therefore the same as that of the Group (Plate 1, Figure B). Since the coal is located high in the local geologic section, it crops out at numerous places in the county (Localities 22, 26, 27, 40), and is easily accessible for mining. By far the greatest proportion of the coal in Allegheny County was located south and west of the Ohio-Monongahela-Youghiogheny River line, although a considerable area of the county east of Pittsburgh and north of McKeesport, including Penn Hills, was also underlain by the coal. In Pittsburgh proper north of Monongahela River, the coal was limited almost entirely to Schenley Heights and the Squirrel Hill-Hazelwood area (Plate 3).

The U. S. Bureau of Mines estimated the original Pittsburgh coal in place in the county at 1,229,665,000 tons, and present (1969) recoverable reserves are estimated at 13,364,000 tons; about 9 or 10 years production at the present rate. Thus, 220 years after mining began on Coal Hill, the Pittsburgh seam will be exhausted in Allegheny County.

The Upper Freeport coal, which has replaced the Pittsburgh coal as the principal seam mined in Allegheny County, is a good grade of bituminous coal, slightly higher in sulfur and volatile matter than the Pittsburgh coal. It is a good steam and coking coal, but is much more variable in composition and erratic in thickness and extent than the Pittsburgh seam. Except in the area of the "Thick" Upper Freeport, which will be discussed below, the Upper Freeport seam ranges from 24 to 54 inches thick in Allegheny County, with a normal thickness of 42 inches. Locally, however, the coal may be thin, dirty, irregular or entirely absent. At Locality 11 the coal is about three feet thick (see Figure 26) but just one-fourth mile away at Locality 12 (Figure 27) the coal is much thinner. Also, at Locality 10 the Upper Freeport is only several inches thick.

Generally the Upper Freeport coal is a clean single bed with a shale parting up to 2 inches thick from 2 to 5 inches above its base. Erosional channels are locally common, and tend to cut out the roof shale and part or all of the coal, leaving very irregular thicknesses of coal overlain by channel-type sandstone.

The area of the county east of Pine Creek, including all the townships north of the Allegheny except Fawn and Harrison, and including Plum and part of Penn Hills Borough south of the river is the locality of the "Thick" Upper Freeport coal. It is a development of the Upper Freeport coal, formed by an unusual thickening of a "rider" or thin seam of coal overlying the main seam. The "Thick" Upper Freeport is characterized by the presence of the typical single coal bed about 42 inches thick, overlain by a 5 to 10 inch thick high ash layer, and above that, an upper coal of variable thickness, ranging from 30 to 40 inches. This upper bed is somewhat less pure than the lower, and may in part be a cannel coal (Richardson, 1932; Hughes, 1933).

As the uppermost unit of the Allegheny Group, the level of the Upper Freeport seam is 600 to 630 feet below the level of the Pittsburgh coal. It is, therefore, nearly everywhere below the ground surface in the county, except locally in the valley of Pine Creek north of Etna, (Localities 10, 11 and 12) and in the Allegheny and Bull Creek valleys (Locality 17) north and east of Tarentum, where erosion has exposed the Allegheny Group (Plate 1, Figure B). So far, exploratory drilling, records of oil and gas wells, and mining reveal that the Upper Freeport is present everywhere in the county; however, coal thicker than 28 inches, constituting present-day minable reserves, is confined roughly to the area east of a north-south line through Pittsburgh, with the "Thick" Upper Freeport confined to the northeast, as noted above.

Recoverable reserves of the Upper Freeport coal in the county, based on 1953 data, are estimated at 450,000,000 tons. Since coal mined in Allegheny County averages about 5,300,000 tons per year, the remaining Redstone, Pittsburgh, and Upper Freeport coal reserves are sufficient for about another 100 years of production.

MINE SUBSIDENCE

by

Richard E. Gray
General Analytics, Inc.

Although coal was first mined in western Pennsylvania over 200 years ago, mining methods and centers of operation were such that surface subsidence was not a major problem. Many years ago coal was mined in largely agricultural areas. At that time mining companies purchased mineral rights, which they are still exercising today; thus, rapidly expanding suburbs and decentralization of industry now are faced with surface subsidence problems.

The mining method commonly used in this area is room and pillar mining (see Figure 61). This method normally progresses in two phases. The initial phase consists of opening a system of entries to provide access, ventilation and haulage ways. The entries and cross entries ("butts") are generally driven to the farthest reaches of the property before extensive mining is initiated. Mining of the seam is then done by driving rooms off the butts at intervals so as to leave pillars of coal between rooms. This primary, advancing, phase is continued until an area is exhausted by room mining, leaving about half of the coal still in the

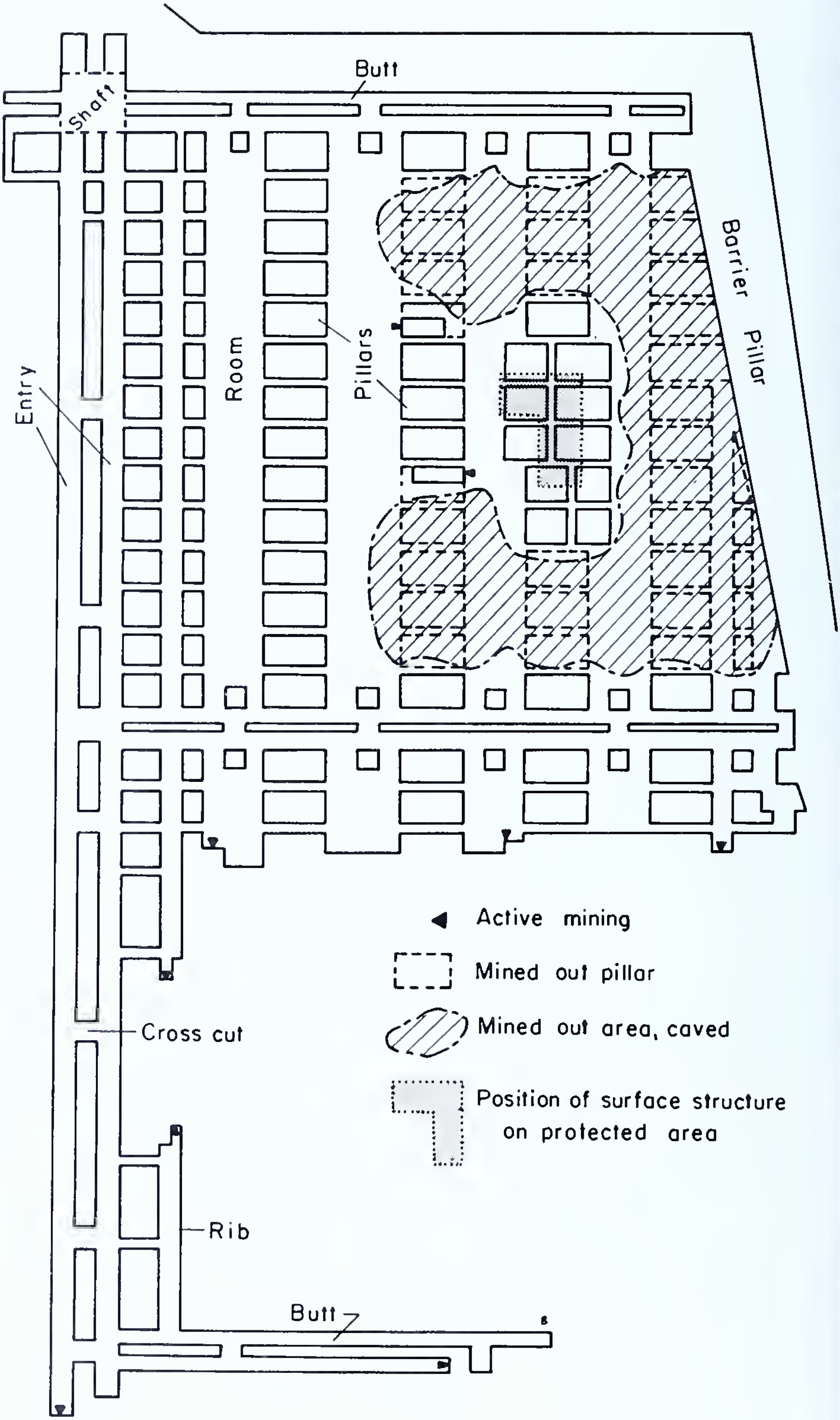

Figure 61. Plan of hypothetical coal mine showing system of room and pillar retreat mining.

pillars. The secondary, retreat, phase is then begun, starting with pillar extraction at the distant end of the mine, and retreating toward the entries, allowing the roof to collapse. These pillars are removed section by section to permit a regular collapse of the overlying strata, resulting in surface subsidence.

Thus, nearly complete extraction is possible today in many mines, whereas previously, less efficient methods required that pillars be left in place, which, in turn, gave support to the ground surface. Although mining operations in coal seams other than the Pittsburgh and Upper Freeport or in clay seams may present local subsidence problems, the major subsidence problems of western Pennsylvania are associated with the two seams which are mined in the highly populated Pittsburgh area—the Pittsburgh and Upper Freeport coals. These can be divided into three distinct subsidence problems. One is the recent development of the Upper Freeport seam at considerable depth in the northerly portion of Allegheny County. The second is in the central portion of the Pittsburgh area where new housing developments, schools and light industries are being constructed on hilltops where the mined Pittsburgh seam occurs at shallow depths. The third is in the southern portion of the Pittsburgh area where mining is being conducted at depth in the Pittsburgh seam.

Buildings constructed several hundred feet above mined out coal seams in western Pennsylvania generally do not suffer major damage from subsidence. Where the interval between the ground surface and the abandoned coal mine is less, a detailed investigation is required prior to construction to fully evaluate the probability of future movements of the ground surface and their effect on the proposed structure. In the areas of active mining north and south of Pittsburgh, mining companies are required to leave coal pillars for support of all homes present at the time of the Bituminous Mine Subsidence and Land Conservation Act of 1966. For new homes this law requires that the deed indicate the existence of, or lack of, subsurface support. Prior to mining, the coal company is to contact property owners and assign a price for leaving coal pillars as support. If the price is not acceptable to the property owner, then the Secretary of the Commonwealth Department of Mines and Mineral Industries will assign a mediator to determine just compensation for the coal to be left in place for surface support.

Generally, where coal pillars are left as support, 50 percent of the coal is left in place below a building (see Figure 61 and Figure 62). While such a purchase is often a financial burden to landowners, and the loss of a valuable source of energy is unfortunate, this is the only current practical means of preventing subsidence damage in areas of active mining.

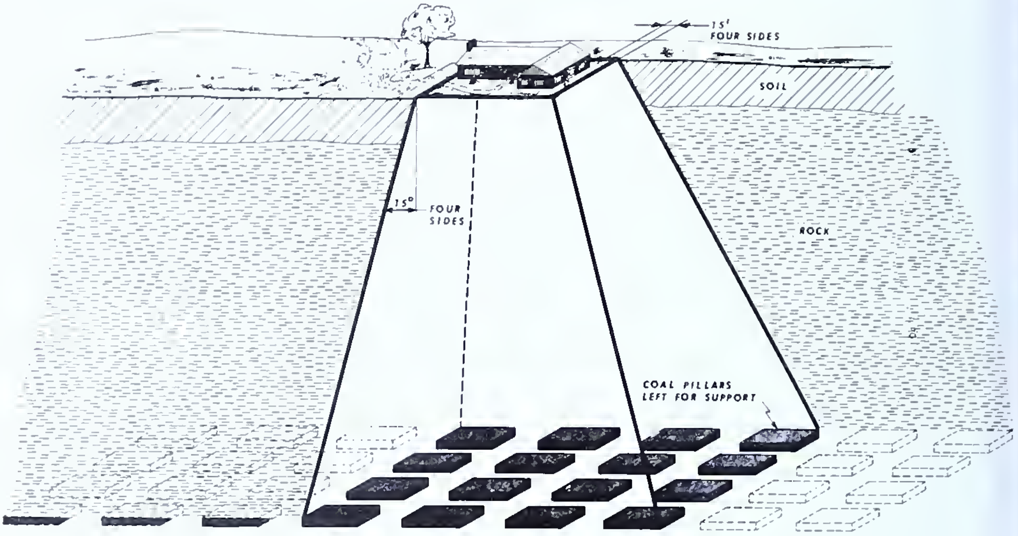

Figure 62. Method of supporting a structure. Adapted from Gray and Meyers, 1968.

Changes in conditions within old mined-out coal seams may sometimes cause local surface subsidence even where pillars have been left. For instance, the underclay of the Pittsburgh coal, where present, undergoes a loss in strength when exposed to air or water, leading to deterioration of the floor beneath coal pillars and a resulting reduction of the effective support area of the pillars. If a pillar then fails, the load is increased on the surrounding pillars, which may eventually also fail, leading to collapse of the mine roof and consequent surface subsidence.

Mine fires which destroy coal pillars left in place in abandoned mines can also result in surface subsidence. Fortunately, most fires are relatively limited in areal extent, and where damage to structures is likely, local communities can obtain the assistance of the U. S. Bureau of Mines and the Pennsylvania Department of Mines and Mineral Industries in controlling fires.

In both the above cases, the effect on the ground surface is dependent mainly on the areal extent of pillar failure and the type and thickness of rock above the mine.

Where mining has taken place, and pillar support is considered insufficient, several methods of additional support are available. They are complete filling of a mined area, construction of piers within the mine, drilled piers, and stabilization utilizing grout columns.

Complete filling of the mined area may be accomplished during mining, by backfilling with rock or mine waste, or subsequent to mining, by

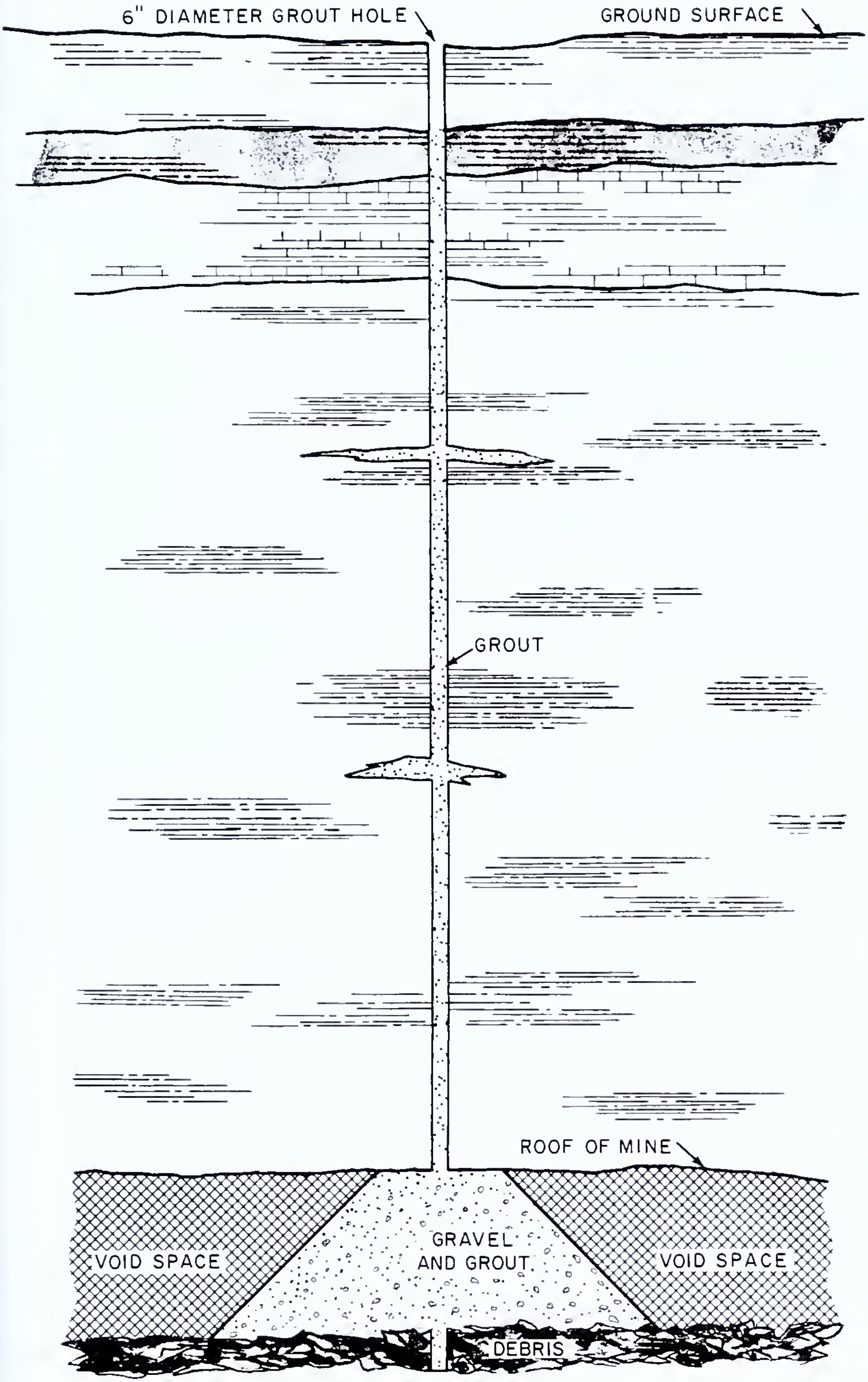

Figure 63. Grout column. Adapted from Gray and Meyers, 1968.

pumping such materials as cement grout, crushed slag, fly ash, or sand into the mined out areas until the void spaces are as completely filled as possible. This is a very high cost technique, and is utilized only in rare cases.

Construction of concrete piers within old workings is undertaken only where there is good access to the area involved, where the area is dry, that is, above the water table, and where the roof rock is relatively strong. Access may be by large diameter boreholes or from old entries.

Drilled concrete piers may be used where the depth to the mined area is generally not in excess of 50 feet. A hole of 18 to 48 inches in diameter is drilled to the base of the mine, a steel casing is inserted and filled with concrete to act as support for the structure.

Subsurface stabilization generally utilizes the placement at selected spacings of conical supporting columns of cement grout and gravel to form concrete piers in the mine and injection of cement grout in the rock above the mine. This reduces the span length of unsupported openings in the mine and strengthens broken rock strata in the roof above the mine. Emplacement of the grout column is by means of boreholes from the surface (see Figure 63). This is the most generally used technique in the Pittsburgh area to provide support for structures located 50 to 150 feet above old mines.

With a history of over 200 years of coal mining in this area, it is imperative that each site be investigated prior to construction of a home or other building to ascertain the effect of either past or future mining operations on the structure.

PETROLEUM AND NATURAL GAS

by

W. R. Wagner
Pennsylvania Geological Survey

Petroleum and natural gas were significant in the development of Pittsburgh and Allegheny County, from the 1880's to the 1920's, but since then, production in the county has dwindled. In 1967 no oil wells and only one gas well were drilled. Indicative of oil's historic role, however, are 288 old oil wells in the county which still produce almost 97,000 barrels of oil per year. In contrast, the famous Bradford Oil Field in McKean County produced over 2½ million barrels in 1967, more than 25 times the amount contributed by Allegheny County.

Oil and gas are found at depths of about 1200 to 2800 feet in Mississippian and Upper Devonian age sandstones. Figure 64 shows the location of the oil and gas fields of the county, the larger ones being named. Most of these fields are now abandoned. Contrary to common belief, oil and gas do not fill hollow underground caverns, but actually occur in the pore spaces between grains of sand. The sandstones containing the oil and gas were deposited in environments similar to those in which sandstones now at the surface were laid down. These environments were stream channels and shoreline features such as beaches and offshore sand bars. Some of the outcropping sandstones of the Glenshaw Formation in Allegheny County are deep enough in subsurface in Greene County, Pennsylvania and in northern West Virginia to contain oil and gas.

Depositional conditions rather than structural geology were probably the main factors controlling the location of the oil and gas fields. Where the depositional environment favored the development of porous (having void spaces between grains) and permeable (having void spaces that are interconnected) sandstone, in many cases the sandstone subsequently became an oil or gas reservoir. Layers of impervious shale or claystone above and below the sandstone acted as seals to prevent the escape of oil and gas from the reservoir.

In some cases, the location of the field is influenced by geologic structure, especially folding. The three subsurface fluids, gas, oil, and water tend to separate on the basis of gravity. Gas, being the lightest, moves to the crest of anticlines, water tends to remain in the synclines because it is the heaviest, and oil lies in between. The occurrence of a large gas field on the crest of the Murrysville Anticline at Murrysville exemplifies this principle.

Commercial oil production in Pennsylvania began with the drilling of the Drake Well in Venango County near Titusville in 1859. Oil exploration slowly moved south and in 1886 the Mt. Nebo Field was discovered in Ohio Township, Allegheny County. Between 1886 and 1904 almost all the oil fields of the county had been found and the local oil industry started its slow decline to the present day.

The McDonald Oil Field, in Allegheny and adjacent Washington County, discovered in 1890, was second in volume only to the Bradford Field. In 1892 it produced eight million barrels of oil; this is almost twice the amount of oil produced in Pennsylvania in 1968. The field included two famous wells, the Mathews Number One and the Mevey Number One, which set production records that have never been equalled in the Appalachian area. These wells at first produced between 500 and 860 barrels of oil per hour. The productive sandstones of the field lay at depths of 2090 and 2215 feet below the Pittsburgh coal and struc-

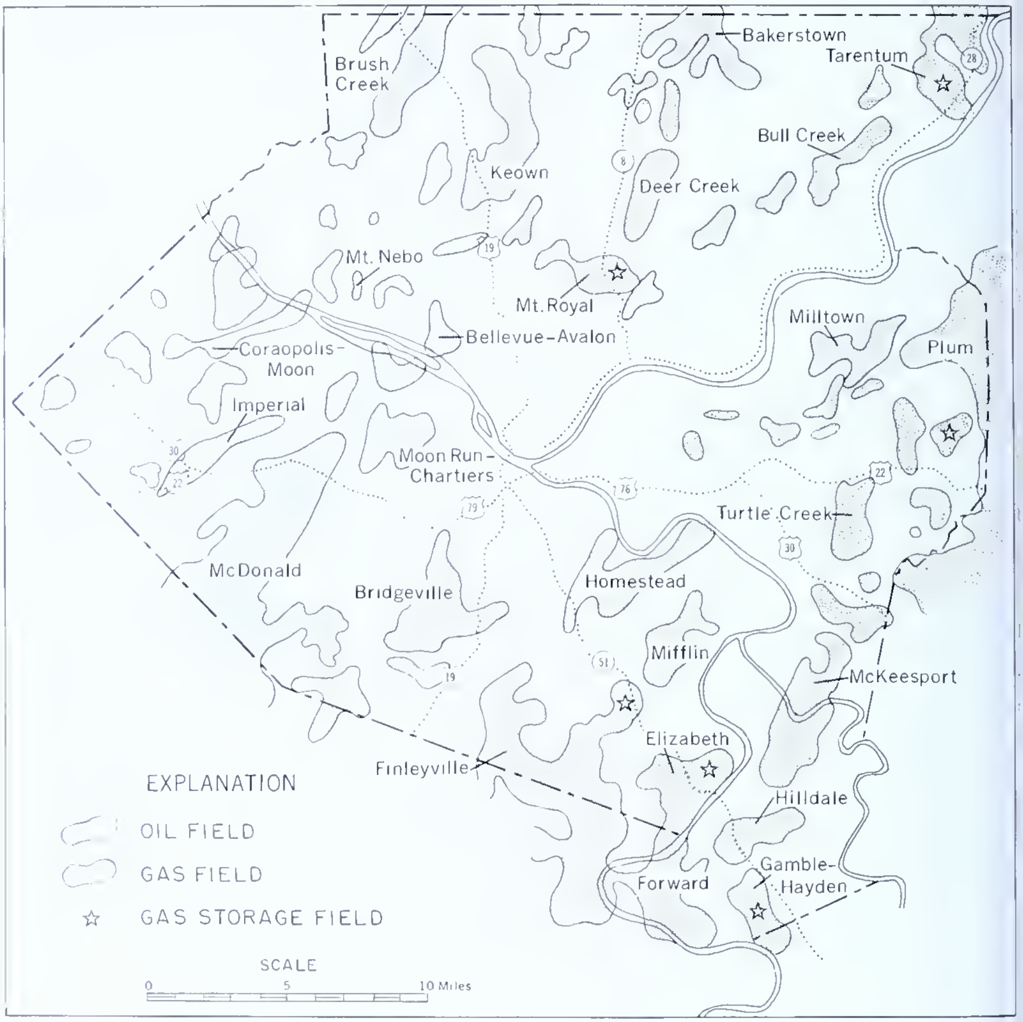

Figure 64. Oil and gas fields of Allegheny County. Adapted from Lytle and Fairall, 1964.

turally were positioned on a fairly flat terrace just west of the Nineveh Syncline. The field still produces some oil and a few derricks can be seen along the Parkway West near the Greater Pittsburgh Airport.

The discovery of gas on the Murrysville Anticline in 1878 led to construction of a gas pipeline from Murrysville to Pittsburgh in 1883. The piping of gas made available to industry a source of fuel cheaper than coal. From that time up to the present natural gas has been the main fuel for heating and for many other industrial purposes in the county.

An example of how not to drill a gas field was succinctly described by Professor Henry Leighton in 1926:

> "The great excitement over the McKeesport gas field in 1920 and 1921 was the result of the drilling of a gas well . . . which at first produced 55,000,000 cubic feet of gas per day, making it the largest and best paying gas well ever drilled." (It has since been superseded by larger gas wells.) "Unfortunately, the speculative fever which followed resulted in the drilling of over six hundred wells within an area of not much over a square mile, a very sudden drop in gas pressure, and in the rapid draining of the field. Out of six hundred, or more, wells drilled, four hundred and twenty nine were "dry holes" and the production in many others was slight. Between the honest but unintelligent projects and the unscrupulous promoter some $20,000,000 were expended, and the return in gas amounted to $2,000,000. A few wells, intelligently placed, could have drained the field . . . and yielded a good return for the money expended."

Since 1921 Pennsylvania has consumed more gas than it produces. Today, about 85 percent of our gas consumption is imported via pipeline from other states. In summer when the demand for gas is low the pipeline gas is pumped into underground storage reservoirs in the State. These reservoirs are old, depleted gas fields that have been converted into natural "storage tanks". During the winter months of peak demand the gas is released from the storage fields and piped to homes and factories. Allegheny County has six storage fields, the location of which are shown on Figure 64.

SURFACE AND GROUND WATER

by

Louis Heyman
Pennsylvania Geological Survey

With Pittsburgh at its center, Allegheny County encompasses one of the most highly industrialized areas in the United States. Large quantities of fresh clean water are required to supply the needs of the people and many industries of the county.

Located in a part of the country where precipitation is ample, averaging 36.08 inches at Pittsburgh and 42.03 inches at Freeport, and well distributed throughout the year, this area has never lacked sufficient surface water supplies. The streams of the Pittsburgh area formerly were often subject to floods; they are now nearly completely controlled by dams.

Many fine springs, formed where part of the water that sinks into the ground reappears at the surface, formerly existed in the Pittsburgh area. The best tasting spring water comes from the base of the Ames limestone, the carbonate rocks of the Benwood and from the Morgantown sandstone. Spring water issuing from the base of coal beds is usually acid and bad tasting. Now, the spread of residential areas and caving due to extensive coal mining has led to local disruption and pollution of many springs.

Smaller communities, such as Shaler Township, Etna, and Sharpsburg in the Allegheny Valley, and West View-Ross Township and Coraopolis on the Ohio, supply their entire needs from wells, but the larger towns and cities ordinarily depend on surface water. The volume of water in the rivers and larger streams should be more than sufficient to meet the water requirements of cities and towns, but pollution of most of the smaller streams and all of the larger, has made adequate surface water supply a serious problem. In the recent past, the recognition of the absolute necessity for plentiful clean water has become general. This has led to the passage of legislation such as the new Clean Streams Law and the Sewage Facilities Act, the establishment of a water-quality evaluation network and watershed management programs and State Health Department enforcement of pollution controls. In the next few years, a substantial restoration of the former high quality of the local surface waters is anticipated.

Pennsylvania to Permian age rocks are a minor source of ground water. These shales, claystones and sandstones, with minor limestones and coal beds, usually yield sufficient water for farm and small domestic needs but supply only a minor proportion of current industrial and large population consumption. The better yields are obtained from the various sandstones, of which the Morgantown sandstone of the Casselman Formation is probably the best for consistent supply; the Benwood of the Monongahela Group is also a reliable source. In other portions of the geologic section, ground water usually occurs at the top or base of an impermeable unit, or in communicating joint systems.

At increasing depths, the water in the rock becomes increasingly saline, until it is unfit for use. The lower portion of the Allegheny Group, and all underlying rocks, yield only brine within Allegheny County. Throughout the county, any well which penetrates more than about 100 feet below the level of the nearest major stream may encounter saline water (Piper, 1933). These stream levels vary from 682 feet above sea level on the Ohio River in the western part of the county, 727 feet on the Monongahela in the southeast, to 745 feet above sea level on the Allegheny River in the northeastern part of the county. At the Point, normal pool level of the rivers is 710 feet.

At many places southwest of Pittsburgh, the water in the aquifers above the Pittsburgh coal has drained into the mine workings, especially where there has been extensive roof breaking and subsidence. The underlying beds, down to the Morgantown sandstone, are commonly shaly and yield little water. Under these conditions, household water must be obtained from surface sources, or in rural areas, from rain catchments and cisterns.

The major sources of ground water are the extensive alluvial deposits which partly fill the valleys of all the major and many of the minor streams. The valley deposits of the Allegheny and Ohio Valleys (Figures 16, 57) are by far the most important source of ground water in the Pittsburgh area, and probably will be increasingly exploited in the future. The origin of these deposits is discussed in Section VII.

The alluvium in these river valleys consists of sand and gravel containing scattered cobbles. The permeability of the deposits may vary within relatively short distances owing to changes in sorting of the sediments; thus, yield will fluctuate between otherwise similar wells. The average thickness of the alluvium is about 60 feet, but may range from 30 to 85 feet in thickness. The sand and gravel is overlain by younger fine sand and silt up to 25 feet thick. The thickness of the alluvium remains fairly uniform across the valleys, but thins abruptly near the valley walls (Figure 57). The width of the permeable sand and gravel averages somewhat less than a mile.

The Monongahela Valley received alluvium contemporaneously with the Ohio and Allegheny valleys, but since it drains the area to the south, which contains sedimentary rocks, the material carried and deposited was chiefly fine sand, silt and clay. Gravel which the glaciers supplied to the Allegheny-Ohio drainage system is lacking in the Monongahela, Youghiogheny, and Chartiers Creek valley fills and the finer-grained alluvium of these south-originating streams is less permeable, with ground water yields consequently much smaller.

The Allegheny-Ohio valley alluvium forms the Pittsburgh Triangle up to Grants Hill, with a notable extension along the Strip on the northwest edge of Schenley Heights. This deposit is the chief source of water for air conditioning in the office buildings of downtown Pittsburgh (Van Tuyl and Klein, 1951).

Most of the water derived from the valley fill is supplied by recharge from the rivers, and fluctuations in the water level in the alluvium are due to changes in withdrawal rate. The ground water is satisfactory for most ordinary uses, containing less suspended matter, bacterial contaminants and industrial wastes than surface water, all of which are in whole or part removed during movement through the alluvium during recharge. On the other hand, the water is harder and contains more iron and manganese, picked up during residence in the sand and gravel.

It is ordinarily not polluted, although derived from a highly polluted source; however, such measures as chlorination and filtration are routine where the ground water is destined for human consumption (Adamson and others, 1949).

Yields from drilled wells in the alluvium range from less than 100 gallons per minute to over 1,000 gallons per minute. One large dug well, twenty-four feet in diameter, has been pumped continuously at 3280 gallons per minute and has an estimated capacity of over 9,000 gallons per minute (Adamson, op. cit.).

Estimates of total ground water withdrawal in Allegheny County vary from 85 to over 100 million gallons per day; this volume is apparently steadily increasing. The greatest proportion of this water, about 80 to 90 percent, is from the alluvium; the remainder from consolidated rock aquifers. The principal users are municipal water systems, that use from 17 to 22 million gallons per day and supply an estimated 200,000 residents of the county, and industrial-private consumers that use the remainder. The major users of private well water are in order of volume: metal and metal products manufacturers, office buildings (largely for air conditioning), chemical and allied industries, power and light, cold storage and ice making, food processing, meat packing, and the clay, glass and stone industries.

SAND AND GRAVEL

by

Louis Heyman
Pennsylvania Geological Survey

Sand and gravel is available in large supply in stream deposits of both glacial (Pleistocene) and Recent age. These deposits have been transported and emplaced by normal stream action and were formerly replenished annually in the major streams of this area by floods bringing material down from farther up river.

Since the construction of flood and navigation control dams on the three rivers, movement of coarse sediment downstream has decreased and the long-term outlook is for eventual depletion of the coarser fraction of these deposits.

The sand and gravel dredged from the beds of the Allegheny and Ohio Rivers is most suitable for concrete aggregate, the principal use, since they are to a large degree reworked glacial material. The Monongahela, however, draining a nonglaciated area of sedimentary rocks, contains a high proportion of silt and clay. Cleaning this material to extract usable sand and gravel is more expensive than processing Allegheny and Ohio River gravels, and thus little is used.

Although eventually the river deposits may be depleted, as mentioned above, reserves are very large. One major operator estimates over ten years supply remaining in the Allegheny below Lock 7 at Kittanning, and much more than that in the river above that point.

The Davison Sand and Gravel Company is at present dredging in the Allegheny near Tarentum and Natrona; in the near future they expect to be stripping material from Jacks Island just above Natrona. The Dravo Corporation is working the Ohio River gravel deposits near East Liverpool, Ohio.

Sand and gravel also occur in the old high level river terraces discussed in Section VII. They contain a somewhat higher proportion of weathered pebbles than the river deposits. The extent of these terrace deposits have been defined by drilling for water and foundation testing and by various excavations. Among the larger deposits of this type are those at Natrona and Harmarville on the north bank of the Allegheny. McCrady, Inc. is at present conducting large operations in the terrace gravels at Harmarville, near the Pennsylvania Turnpike and the B & LE railroad rights-of-way (Locality 16). In most areas of the county, however, the level surfaces and good drainage of these terraces makes them too valuable as building sites to allow their exploitation for sand and gravel.

SANDSTONE AND LIMESTONE

by

Louis Heyman
Pennsylvania Geological Survey

Sandstones occur at various intervals in the stratigraphic column of the Pittsburgh area. They are commonly channel sandstones and change thickness abruptly when traced laterally. Internally, the units are thin-bedded or cross-bedded, with few massive beds, and locally may contain enough iron minerals to cause them to weather yellow or dull brown. These factors limit most of the local sandstones for use as crushed rock and rough stonework.

Where massively developed, even grained and hard, the sandstones have been quarried as dimension block for nearby use in bridge abutments, chimneys and permanent building construction. Concrete and cement blocks, however, have replaced dimension stone for many of these uses.

The major sandstones that locally exceed 25 feet in thickness are: a sandstone about 150 to 200 feet above the Ames limestone, and the Morgantown sandstone, 100 to 150 feet above the Ames, both in the Casselman Formation; sandstones, all in the Glenshaw Formation, from about 50 to 150 feet below the Ames; a sandstone about 200 feet below the Ames, between the Pine Creek and Brush Creek limestones; and a sandstone about 300 feet below the Ames, not far above the Upper Freeport coal at the top of the Allegheny Group. Of these, only the Morgantown and the sandstone in the upper Casselman Formation have been used extensively for dimension stone. Locally, any hard, thin, but fairly uniform bedded sandstone which is easily parted may be used as flagstone for walks and patios.

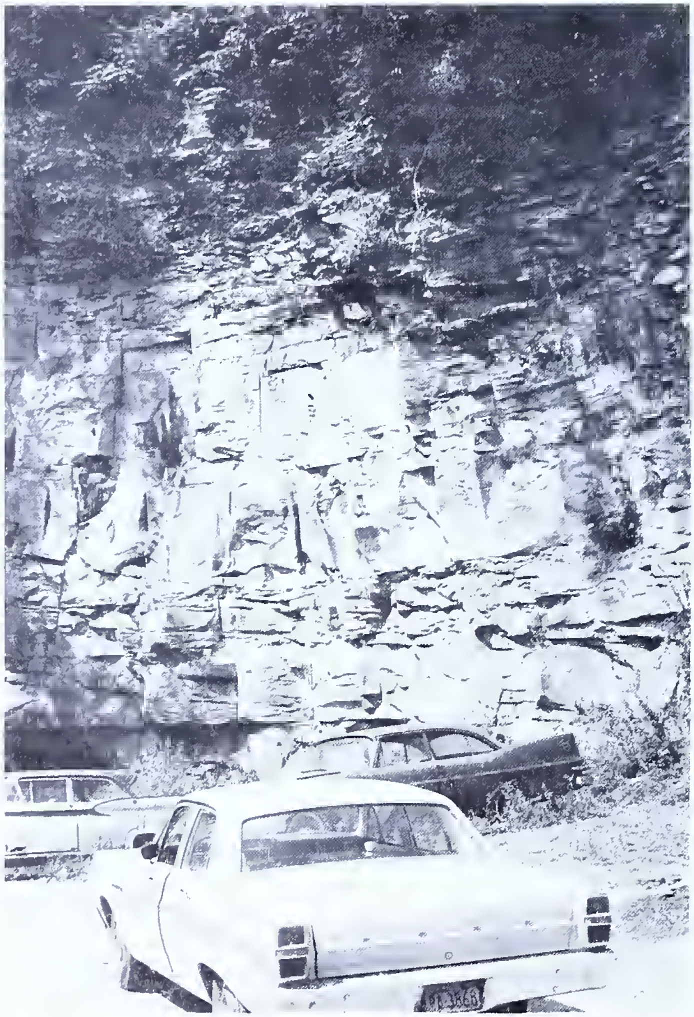

Figure 65. Abandoned sandstone quarry in a middle Glenshaw channel sandstone at Bauerstown. (Locality 8).

At present, local quarries for crushed rock, opened in such units as the Morgantown sandstone, are the only operations of any consequence. Figure 65 shows an abandoned quarry in a sandstone of the upper part of the Glenshaw Formation at Bauerstown (Locality 8).

The chemical composition of a limestone is the chief factor controlling its use, since this will commonly also affect its physical properties, such as crushing strength and resistance to abrasion. Chemical limestone and open-hearth fluxstone must contain at least 98 percent carbonate, although 97 percent is sometimes acceptable. Blast-furnace fluxstone must contain less than 7 percent combined silica and alumina, and less than 31 percent magnesium carbonate. Concrete aggregate must have good resistance to abrasion, and building stone and railroad ballast high crushing strength and resistance to weathering.

Portland cement is made by pulverizing a semifused controlled mixture of lime, silica and alumina. The limestone used for cement should contain less than 6.3 percent magnesium carbonate, and the raw mix can be made up to the correct proportions by adding the proper amount of shale to the limestone; however, alumina plus iron oxide should not exceed 13 percent (O'Neill, 1964).

Agricultural limestone can have a broader range of calcium and magnesium content, but the calcium carbonate content cannot be less than 85 percent; the proportions being controlled by the properties of the soil to which the agricultural lime made from it is to be applied (O'Neill, 1964).

The majority of the limestones in this area are impure, thin- to nodular-bedded, and locally irregularly distributed. An average analysis for the thicker usable Pennsylvanian limestones in this area shows calcium 80 to 85 percent, magnesium carbonate 2.3 to 5.6 percent, silica 5 to 8 percent, and combined alumina and iron oxide 2.4 to 10.8 percent. The local limestones were formerly burned by farmers for agricultural lime, and more recently some has been used as concrete aggregate, building stone, agricultural lime, cement, and fill.

The Benwood carbonate layer of the Pittsburgh Formation is the best developed of the local carbonate rocks and has been exploited at various times for most industrial uses except chemical lime and cement. It is impure, dolomitic and comparatively weak, and is now little used except locally as crushed rock.

The Vanport limestone of the Allegheny Group is the only limestone of western Pennsylvania that is used extensively as fluxstone, chemical limestone, and cement. It crops out north of Allegheny County and is quarried in Lawrence, Butler, and Armstrong Counties. Some currently active operations in southern Lawrence County are the Medusa Portland

Cement Company quarry near Wampum and the Mooney Brothers Supply Company at West Pittsburg. In western Butler County the Sechon Limestone Company quarry is located near the junction of Routes 19 and 422, and at West Winfield in southeastern Butler County is the Vanport mine of the Penn-Dixie Cement Corporation.

CLAY AND SHALE

by

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Pennsylvania Geological Survey and U. S. Bureau of Mines

Clay and clay products rank high in economic importance in most of the surrounding counties, but in Allegheny County, their present importance is minor. This is due more to the steadily shrinking area of the county available for clay pits than to a decrease in raw materials or demand for clay products, especially building brick.

Local clay resources include surface clays in terrace and alluvial deposits along the main streams of the area, residual clay formed by weathering of rock in place, and claystones and shales in the outcropping and near surface rocks.

The "terrace clays," chiefly in the Pleistocene Carmichaels Formation are very plastic, but erratic in occurrence and locally mixed with varying quantities of sand or silt. They were much used in the early days for making stoneware, roofing tile and brick. The floodplains and stream terraces where this material occurs are now much too valuable as sites for towns, industrial plants, railroads and highways to be used for clay pits.

Suitable residual clay deposits are thin, erratic and usually restricted to areas underlain by carbonate rock. The largest deposits occur where the Benwood carbonate layer of the Pittsburgh Formation crops out on top of broad, flat-topped hills, but these high areas usually are occupied by good agricultural soils such as Guernsey and are now more valuable as farmland than as sources of clay.

Claystone and shale are very common in this area, and have been used for a variety of products. Some silica content is necessary for brick making and is usually supplied by an admixture of adjacent siltstone or sandy shale beds, or the normal sand and silt content of the shales and claystones. An excess of silica, or the presence of limestone, pyrite nodules or coaly material renders the claystone or shale valueless for brick making. A certain amount of organic or coaly content, without the other impurities, causes the claystone or shale to swell on being heated. This type of "bloating shale" is used in making lightweight aggregate for concrete blocks.

The 60 to 80 feet of shale and claystone above the Pittsburgh coal in the Monongahela Group has been used extensively for building brick. At Wilkinsburg the sandstone commonly found in the middle of this sequence is replaced by shale and Milliken Brick Company used the whole sequence for making face and building brick. The roof shale separating the main bed of the Pittsburgh coal from the overlying roof coal has been used for medium duty refractories and acid-resistant brick.

In the Conemaugh Group, the Birmingham shale and the red and green claystones of the Pittsburgh reds furnish about half of the county's production. Milliken's Harmarville works (Locality 45) produces face and building brick from the Pittsburgh reds and the underlying shale and claystone. The clay rich rocks above the Upper Freeport coal in the northeastern part of the county are also suitable for making brick (see Figure 14, abandoned clay pit at Creighton).

Generally, the Conemaugh rocks are most useful for common types of ceramic products, such as building brick and sewer and drain tile. However, the claystone beneath the Brush Creek Coal has been exploited for making buff face brick and refractory brick, and in the central part of the county, shales occur with good potential for making lightweight aggregate.

Flint clay is a dense, brittle, conchoidally fracturing, non-plastic claystone. It is commonly interbedded with, or occurs as nodules in, the more plastic underclays, but may occur alone. Flint clay is highly refractory, resisting heat and chemical attack, and is valuable for making such ceramics as firebrick and furnace linings. Comparatively little refractory clay occurs in Allegheny County, but the claystone directly beneath the Upper Freeport coal, and the Bolivar claystone occurring about 15 to 30 feet beneath the Upper Freeport coal, have been mined in the Kiskiminetas Valley and in eastern Allegheny County. The claystone directly beneath the Upper Freeport coal is a semi-flint clay, whereas the Bolivar claystone is an extremely variable unit, changing from a flint clay to soft plastic claystone in a few feet.

Almost the entire output of claystone and shale in Allegheny County now goes into building and face brick. Two operations, one at Large and the other at Freeport, still make refractory items for the steel industry, but do not use local raw materials.

APPENDIX 1

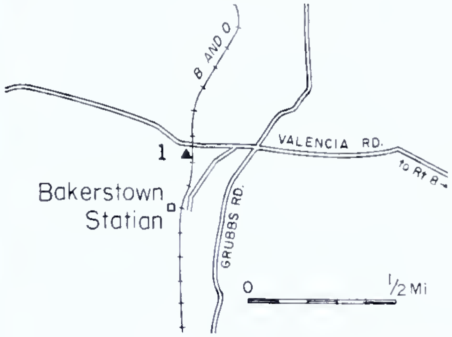
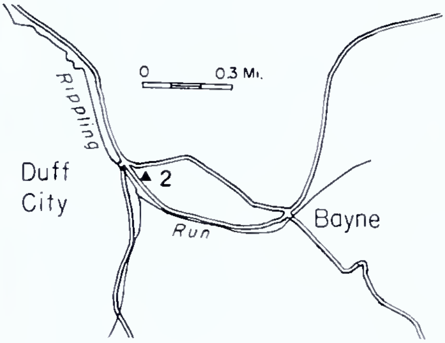
TABLE OF LOCALITIES

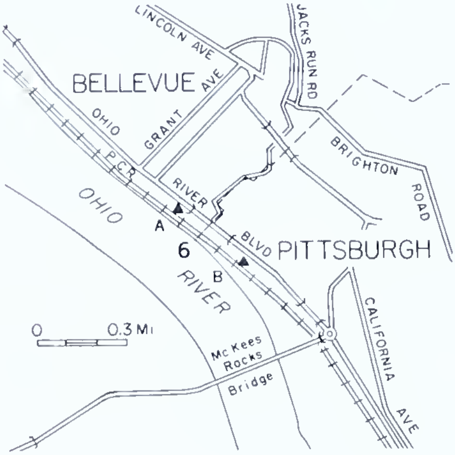
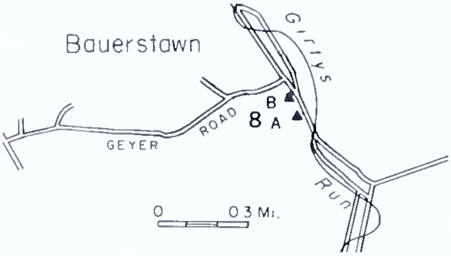
In this table the data discussed in the text are summarized. The first column, *Locality Number,* refers to the number shown on the county locality map (Plate 1, figure D). A more detailed *Location* is given in column two. The *Rocks Exposed* column indicates the stratigraphic interval of the outcropping rocks at the specific locality; the abbreviations used in the column are listed below:

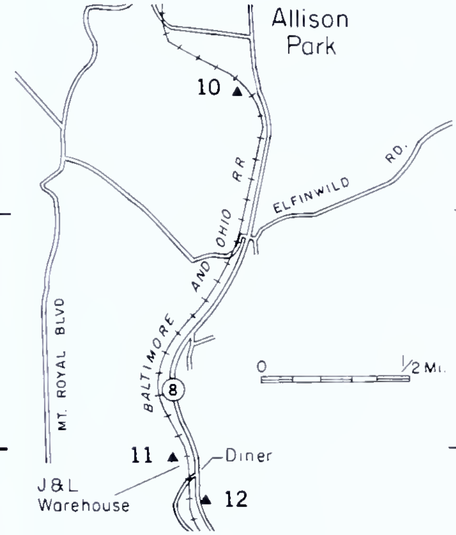
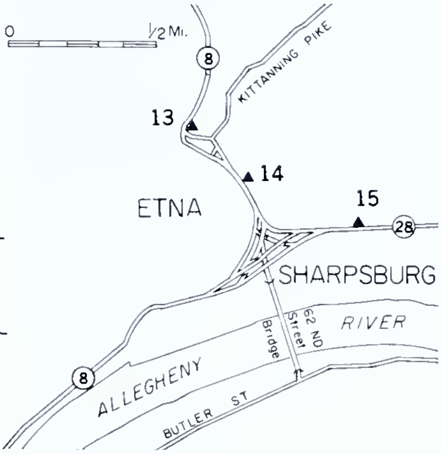
	Waynesburg Formation	W
	Pittsburgh Formation	P
upper	Casselman Formation	Cu
middle	Casselman Formation	Cm
lower	Casselman Formation	Cl
upper	Glenshaw Formation	Gu
middle	Glenshaw Formation	Gm
lower	Glenshaw Formation	Gl
	Freeport Formation	F

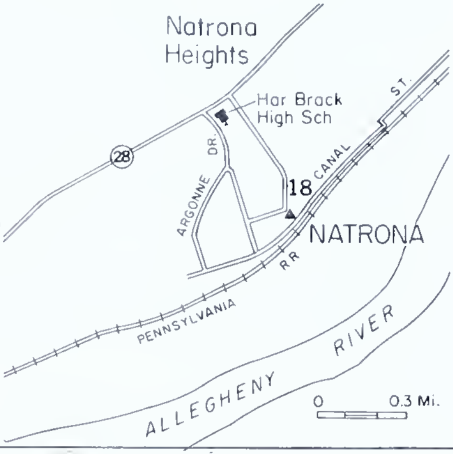
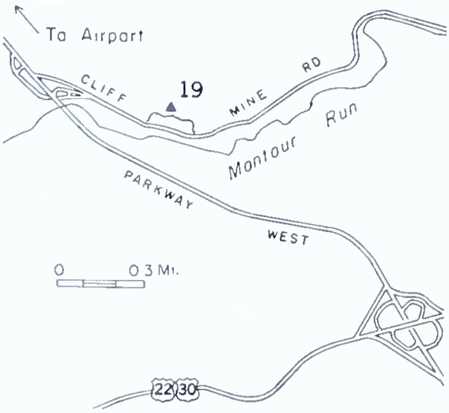
The *Geologic Features* that may be observed at the locality are noted in the last column and in parentheses are the figures and page numbers where the features are discussed in the text. Under *Comments,* are noted hazardous traffic conditions, local color, etc. Abbreviations used in this column are:

conglomerate	cgl.
dolomite	dol.
junction	jct.
limestone	ls.
sandstone	ss.
shale	sh.
siltstone	slt.

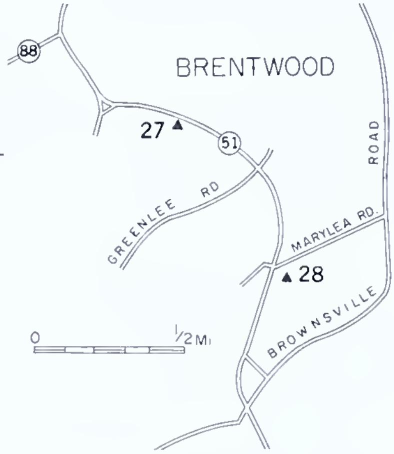
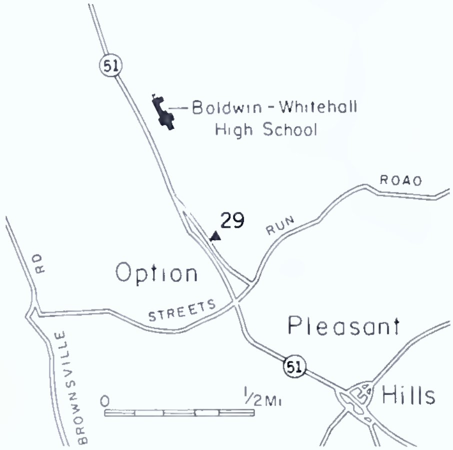
LOCALITY NUMBER	LOCATION	ROCKS EXPOSED	GEOLOGIC FEATURES, PAGES WHERE DISCUSSED, COMMENTS
1	 B AND O VALENCIA RD. To Rt 8 1 Bakerstown Station GRUBBS RD. 0 ½ Mi	Cm to Cl	Faulting caused by slumping; erosional surface at base of Morgantown ss. (Fig. 38 & p. 64-66). Comment: Most complex structure known in county. Many more faults are present than are shown on Fig. 38.
2		Gm	Small anticline in ss. (p. 68). Fold is not present in underlying sh. exposed between road and stream. Comment: At curve of narrow road; hazardous for large groups.
3	Stoops Ferry on Route 51.	Gl	Channel ss.; massive cross-bedding (p. 52).
4	Route 51, south end of Sewickley Bridge across Ohio River.	Gl	Fossiliferous Brush Creek ls. & open-water sh. (p. 23 & 51-52). Jointing in sh. almost parallel to road (p. 62). Comment: Road under construction at time of publication.
5	Ohio River Blvd. at crest of hill between Glenfield & Hayville, 0.6 miles west of Glenfield Road.	Gl	Fossiliferous marine sh. 1′ thick (p. 23). Jointing parallel to road (p. 62). Small anticline at road level (Fig. 41 & p. 68). Comment: High speed traffic and narrow road shoulder.

LOCALITY NUMBER	LOCATION	ROCKS EXPOSED	GEOLOGIC FEATURES, PAGES WHERE DISCUSSED, COMMENTS
6	 LINCOLN AVE JACKS RUN RD BELLEVUE AVE GRANT OHIO PCR RIVER BLVD OHIO RIVER A 6 B BRIGHTON ROAD PITTSBURGH CALIFORNIA AVE 0 0.3 Mi McKees Rocks Bridge	Gl	A. Open-water sh. & slt. at base of cliff, overlain by gray sh. with plant remains. Above sh. is channel ss. with basal contact well-exhibited (Fig. 30 & p. 38 & 52). Honeycomb weathering in ss. (Fig. 6 & p. 11). B. Excellent cross-bedding in channel ss. (Fig. 19 & p. 33-35). Comment: Dangerous along high speed tracks of Penn Central RR.
7	Outcrops along McKnight Road 1 mile north & south of Siebert Road.	Cl to Gu	Pittsburgh reds and Ames ls. (fossiliferous) (p. 54).
8	 Bauerstown Girtys Run B 8 A GEYER ROAD 0 0.3 Mi.	Gm	A. Thick bedded channel ss. & thinner bedded flank ss. in abandoned quarry (Fig. 65 & p. 38 & 124). B. Sh. & slt. replace the channel ss. Comment: A is a used car lot. Both A & B are good for large groups.
9	Route 8 between Millvale & Etna.	Cl to Gm	Pittsburgh reds (p. 40), & Ames ls.; red beds subject to sliding. Stream channel ss. behind homes in Etna; probably same ss. that is at Localities 8A & 14.

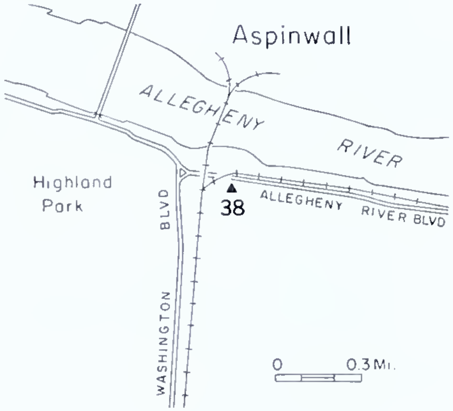
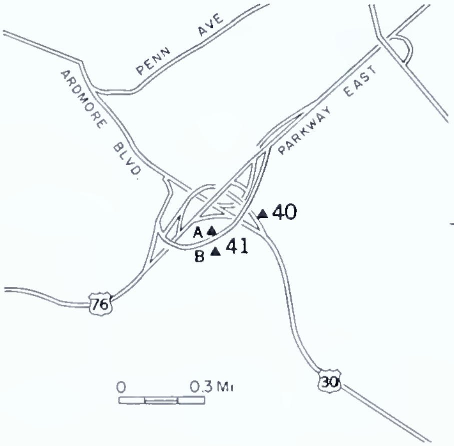
LOCALITY NUMBER	LOCATION	ROCKS EXPOSED	GEOLOGIC FEATURES, PAGES WHERE DISCUSSED, COMMENTS
10	 Allison Park 10 ELFINWILD RD. BALTIMORE AND OHIO RR MT. ROYAL BLVD 8 0 ½ Mi. 11 Diner 12 J&L Warehouse		Axis of Kellersburg Anticline, open-water strata dipping gently to northwest off anticlinal crest (Pl. 1c & p. 23, 51 & 110). Upper Freeport coal a few inches thick. Comment: Allison Park RR Sta.
11		Gl to F	Upper Freeport coal 3′ thick with underlying lake deposits (Fig. 26 & p. 48, 49 & 110). Comment: Jones & Laughlin warehouse parking lot.
12		Gl to F	Ss. & sh. of stream environment replace lake deposits of Locality 11 (Fig. 27 & p. 48, 49 & 110).
13	 0 ½ Mi. 8 KITTANNING PIKE 13 14 15 ETNA 28 SHARPSBURG 62 ND Street Bridge RIVER ALLEGHENY 8 BUTLER ST	Gm	Type area of Pine Creek ls. (Fig. 28 & p. 23 & 50); ls. rises to north toward axis of Kellersburg Anticline (p. 68); underlying sh. & slt. grade northward into open-water ss. along length of outcrop (p. 50 & 51). Excellent fossil collecting in ls. & underlying sh. Comment: Sharp road curve—dangerous for large group.
14		Gm	Channel ss. cut & fill (Fig. 29 & p. 38 & 50).
15		Cl to Gu	Excellent fossil collecting—invertebrates from Ames ls., plants & fish scales from black sh above Duquesne ls. (p. 83). Comment: Fine for large groups. Park along westbound lane of Route 28.

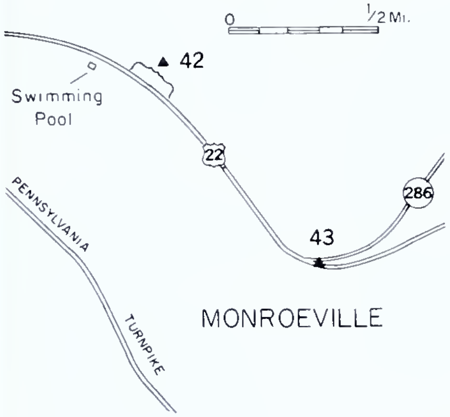
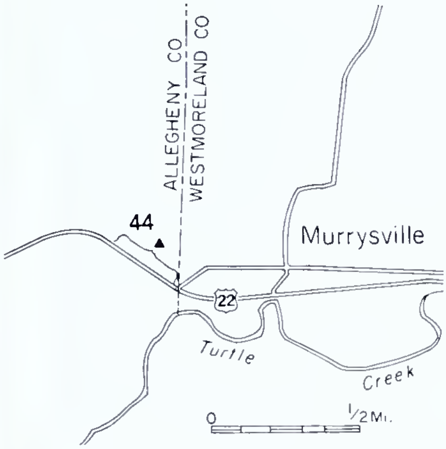
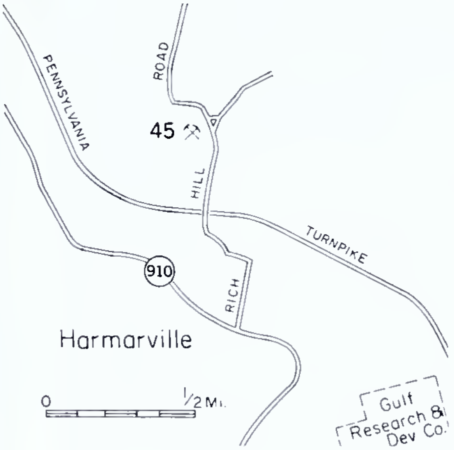
LOCALITY NUMBER	LOCATION	ROCKS EXPOSED	GEOLOGIC FEATURES, PAGES WHERE DISCUSSED, COMMENTS
16	0.6 miles north of jct. of Pearl St. & Route 28 in Acmetonia.		Pre-glacial Allegheny River sand & gravel 200′ above present river level (p. 90 & 123). Comment: Active quarrying operation.
17	Bull Creek Road 3.1 miles north of Tarentum at jct. of McDowell Run.	Gl to F	Upper Freeport coal (p. 48 & 110-111).
18	 Natrona Heights Har Brack High Sch 28 ARGONNE DR ST. CANAL 18 NATRONA RR PENNSYLVANIA RIVER ALLEGHENY 0 0.3 Mi.	Cl	Cross-bedded, channel ss. (Fig. 35 & p. 52 & 60); irregular fractures caused by mining of underlying Upper Freeport coal. High terrace gravels blanket the top of the hill (p 90).
19	 To Airport CLIFF 19 MINE RD Run Montour PARKWAY WEST 0 0.3 Mi. 22 30	Cl to Gu	Channel ss. showing though-shaped cross section, cut & fill, irregular basal contact, basal cgl., thin coal seams, fossil plants in lower part of channel, decrease of grain size & bed thickness upward from channel base (Figs. 17, 18 & p. 31-33). Fossiliferous Ames ls. below channel ss. Comment: Excellent for large group to study channel ss.
20	Bridgeville exit & entrance to Interstate Route 79.	P	Complete exposures of the Benwood Carbonate layer & the underlying sh. & fresh-water carbonate rocks (Fig. 33 & p. 16 & 57).
21	Long, high cut west of Heidelberg on Interstate Route 79.		Comment: Spectacular highway cuts. Locality 20 good for large group.

LOCALITY NUMBER	LOCATION	ROCKS EXPOSED	GEOLOGIC FEATURES, PAGES WHERE DISCUSSED, COMMENTS
22	Painters Run Road from Bower Hill Road to McMillan Road.	P	Pittsburgh coal showing roof coal & main bed (p. 57), cleat (Fig. 36 & p. 60 & 61), & old mine entrances. Folding in overlying sh. caused by mining subsidence (p. 111).
23	Howard Johnson restaurant, Route 19 & Gilkeson Road, Mt. Lebanon.	P	Benwood Carbonate layer showing interbeds of ls., dol., & sh. (Fig. 9 & p. 14-16 & 25, 26 & 57). Comment: Good for large groups to differentiate ls. from dol.
24	Banksville Road (Route 19) from Parkway West to Wenzell Ave.	Cu to Cm	Fine exposures of strata from Morgantown ss. at Parkway to Pittsburgh coal at Wenzell Ave. (Fig. 3 & p. 8 & 54-55). Comment: A fault is present in Figure 3. Can you find it?
25	Park on South Side at end of 21st St.	Cu to Cm	Sequence of coaly sh, fresh-water ls., silty sh, red & green cls. lying between an upper channel ss. & a lower cross-bedded Morgantown ss. (p. 56 & 57). Comment: An abandoned clay quarry for brick making. Fine locality for large group.
26	West Liberty Ave. near Capital Ave.	Pl to Cu	Good exposures of Pittsburgh coal & underlying fresh-water carbonate rocks (p. 56).

LOCALITY NUMBER	LOCATION	ROCKS EXPOSED	GEOLOGIC FEATURES, PAGES WHERE DISCUSSED, COMMENTS
27	 88 BRENTWOOD 27 51 GREENLEE RD ROAD MARYLEA RD. 28 BROWNSVILLE 0 ½ MI	P	Syncline in Pittsburgh roof coal caused by mining of main bed (Fig. 42 & p. 18 & 57).
28		P	Base of Benwood Carbonate layer (p. 57). Comment: An almost complete section of Monongahela Group is exposed along Route 51 from Route 88 to Brownsville Road.
29	 51 Baldwin - Whitehall High School ROAD RUN 29 RD Option STREETS Pleasant 51 Hills BROWNSVILLE 0 ½ MI	P	Differential weathering of Benwood carbonate rock & underlying sh. causes rock falls at base of Benwood (Fig. 34 & p. 57 & 105).
30	Route 51, 1.2 miles north of Large (at Peters Creek).	Cu	Thick channel ss. crosses road & becomes thin both to north & south (p. 55).
31	Route 88 (Library Road) between Lytle Road & Montour RR, 0.8 miles north of entrance to South Park.	W	Thin coals, sh., ss., & carbonate rocks of Dunkard Group. Waynesburg coal exposed (p. 59).

LOCALITY NUMBER	LOCATION	ROCKS EXPOSED	GEOLOGIC FEATURES, PAGES WHERE DISCUSSED, COMMENTS
32	Kennywood Blvd. from Rankin Bridge almost to Kennywood Park.	Cm to Gu	Lower 200′ of Casselman & Pittsburgh reds. Massive ss. is Morgantown with erosional surface at base, basal cgl., & cross-bedding. (Figs. 7, 8 & p. 13, 53 & 54). Thick basal ss. changes laterally to interbeds of ss. & sh. Comment: Kennywood Park underlain by Carmichaels Formation (p. 89 & 90).
33	McKeesport—along RR tracks on west side of Youghiogheny River below 5th Ave. Bridge.	Cl	Faulting caused by ancient landslides (Fig. 37 & p. 63 & 64). Several faults are present & can be recognized. Comment: Good locality for interpretation of simple faulting.
34	Glassport-Elizabeth Road on east side of Monongahela River; between Glassport & Belle Bridge.	Cm to Gu	Ames ls. (poorly fossiliferous) to Morgantown ss. well exposed in cliff (p. 53 & 54). Comment: Narrow 2 lane road.
35	Between Webster & Monessen, Westmoreland Co. (See Plate 2).	Cu to Cm	Stream channel migration (Pl. 2 & p. 35 & 38). Comment: Dangerous 4 lane rd.
36	Mt. Washington-north portal of Fort Pitt Tunnel.	Cu to Cl	Section from Pittsburgh coal near top of hill to Ames ls. near river level (p. 44).
37	Parkway East across from Jones & Laughlin Steel plant.	Cl to Gu	Weathering of the Pittsburgh reds causes rock falls of the Ames ls. (p. 40 & 105). Comment: Dangerous to stop car here.

LOCALITY NUMBER	LOCATION	ROCKS EXPOSED	GEOLOGIC FEATURES, PAGES WHERE DISCUSSED, COMMENTS
38	 Aspinwall ALLEGHENY RIVER Highland Park BLVD WASHINGTON 38 ALLEGHENY RIVER BLVD 0 0.3 Mi.	Cl to Gm	Jointing & landslides in Birmingham sh. (Fig. 31 & p. 61 & 62). Cyclothemic deposition (Table 1 & p. 52, 53 & 59). Fine animal & plant fossil collecting (Fig. 10, 31). Comment: Excellent for large group.
39	Forbes & south Braddock Ave. —hillside behind tennis courts in Frick Park.	Gu	Fossil collecting from Ames ls. Carmichaels Formation of old Monongahela channel covers top of hill (Pl. 3 & p. 91).
40	 PENN AVE ARDMORE BLVD. PARKWAY EAST 40 A B 41 76 30 0 0.3 Mi	P	Cleat in Pittsburgh coal (p. 40, 60 & 61); plant fragments in overlying roof sh; subsidence caused by mining.
41		P	A. Laminated floodplain deposits overlying coal (Fig. 20 & p. 35). B. Thinning & disappearance of slt. layer in sh. sequence.
42	See location map p. 137	Cl to Gu	Ames ls.—excellent fossil collecting (p. 18 & 44).

LOCALITY NUMBER	LOCATION	ROCKS EXPOSED	GEOLOGIC FEATURES, PAGES WHERE DISCUSSED, COMMENTS
43	 0 1/2 Mi. 42 Swimming Pool 22 286 43 PENNSYLVANIA TURNPIKE MONROEVILLE	Gu	Woods Run ls.—fossil collecting from bed several inches thick (p. 44). Comment: Route 22 is a heavily travelled road.
44	 ALLEGHENY CO WESTMORELAND CO 44 Murrysville 22 Turtle Creek 0 1/2 Mi.	Gm to Gl	Even layering of open-water sh. & slt. (p. 23 & 52); 2 fossiliferous ls. layers present—Woods Run? and Pine Creek. Comment: Dangerous road.
45	 ROAD HILL RICH PENNSYLVANIA TURNPIKE 45 910 Harmarville 0 1/2 Mi. Gulf Research & Dev Co.	Gu	Milliken Brick Co. clay pit in Pittsburgh reds and underlying shales for production of face and building brick (p. 127). Comment: Obtain permission to enter clay pit.

APPENDIX 2

GLOSSARY

AQUIFER:	A rock formation or stratum that will yiel water in sufficient quantity to be of consequence as a source of supply (Meinzer).
BARREL:	A barrel of oil is 42 U. S. gallons.
BASE LEVEL:	The level below which a land surface canno be reduced by the erosive power of runnin water. On a grand scale, this is sea level, bu locally this is the level of the beds of the principal streams draining an area.
BENEFICIATION:	The act of improving the grade of ore b various concentration processes.
BLAST FURNACE:	A furnace in which combustion is forced b a current of air under pressure, especially on for the reduction of iron ore to metallic iron
BRACHIOPODS:	A phylum of marine bivalve animals resembling clams. They differ from clams in tha each valve may be symmetrically divided i half along a line from top to bottom of th shell.
BRINE:	Water with a very high salt content.
BRYOZOA:	A phylum of colonial animals that build delicate skeletons which resemble moss or se weed, but commonly may be limy.
CANNEL COAL:	A variety of bituminous coal, uniform, compact and fine grained, with a dull greas luster, conchoidal fracture and which burn with a luminous yellow smoky flame.
CRINOIDS:	A class of marine animals consisting of a cu or "head," from which numerous arms radiat and which contains the vital organs, a jointe stem and roots by which it attaches to th sea bottom. Modern forms are familiarl known as "sea lilies."

DIP:	The angle at which a stratum or any planar feature is inclined from the horizontal.
ESCARPMENT:	A steep face terminating highlands abruptly.
FELDSPAR:	A common group of minerals that are commonly found in sedimentary rock. They are composed of the aluminum silicates of sodium, potassium and calcium.
FLOOD PLAIN:	A nearly level low area bordering streams that is subject to overflow.
FLUVIOGLACIAL:	Pertaining to streams flowing from glaciers or to the deposits made by such streams.
FLUX:	Any substance or mixture which promotes melting by heat.
FORMATION:	A body of rock of approximately uniform character, mappable at the earth's surface or traceable in the subsurface.
FOSSIL:	The remains or traces of animals or plants which have been preserved by natural processes in the earth's crust.
GEOCHRONOMETER:	A device or method for absolute or relative dating of past geologic events.
HABITAT:	The environment in which the life needs of a plant or animal are supplied.
HARDPAN:	An indurated, slowly permeable soil layer.
INDURATED:	A term applied to sediments or other earth and rock aggregates rendered hard by cementation, heat, pressure, grain interlocking or other cause.
MATRIX:	The natural material in which any markedly larger particle, fossil, pebble, crystal, etc. is embedded.
MEANDER:	One of a series of somewhat regular and looplike bends in the course of a stream, developed through lateral shifting of the stream's course.

METAMORPHIC ROCKS:	Rocks formed from pre-existing rocks by heat, pressure and chemical activity without accompanying mass melting or disaggregation of the pre-existing rocks.
NODULE:	A rounded concretionary body found in rocks which can be separated from the matrix in which it occurs.
OSTRACODES:	Tiny crustacean animals with bean-shaped bivalve shells completely enclosing the body.
OUTCROP:	That part of a rock unit which appears at the surface. The verb is *to crop out.*
OXIDATION; REDUCTION:	*Oxidation* is the process of combining with oxygen. *Reduction* is the opposite of oxidation, that of removing oxygen from a compound.
PARENT MATERIAL:	The rock material from which a soil is formed.
QUARTZ:	A common rock-forming mineral. It is composed of silicon and oxygen and has the chemical formula SiO_2.
REFRACTORIES:	Materials capable of resisting the action of heat and chemical reagents.
REJUVENATION:	To stimulate, as by uplift, to renewed erosive activity; said of streams.
SALINITY:	A measure of the total concentration of dissolved solids in a saline water.
SOIL MOTTLING:	Contrasting gray, rusty or orange patches occurring in the soil profile, usually indicating poor or irregular drainage.
STRIKE:	The direction or bearing of a horizontal line on an inclined plane. The inclined plane may be the surface of a layer of rock, a joint, or a fault.
SUBSOIL:	Technically, the "B" horizon of a soil which has a distinct profile; commonly that part of the soil profile lying below the surface layer.

SUBSTRATUM:	Technically, the "C" or "D" horizon of a soil where the soil has a distinct profile. It is that layer of unconsolidated or weathered material which is relatively little affected by organic activity, and is presumed to be similar in composition to the material from which at least a portion of the overlying units have developed.
SUN CRACKS:	Cracks formed by shrinkage of muds composed of clay-size material in the course of drying due to the sun's heat.
TERRACE:	In physiography, any relatively flat, horizontal, or gently inclined erosion surface, commonly narrow and usually with a steep front, bordering a river, a lake or the sea. Successive terraces may have a steplike character. A *Structural terrace* is one due to local flattening of sloping rock layers rather than a flattening caused by erosion.

APPENDIX 3

PERTINENT LITERATURE

Reports preceded by an asterisk (*) are most useful for
field study of Allegheny County geology

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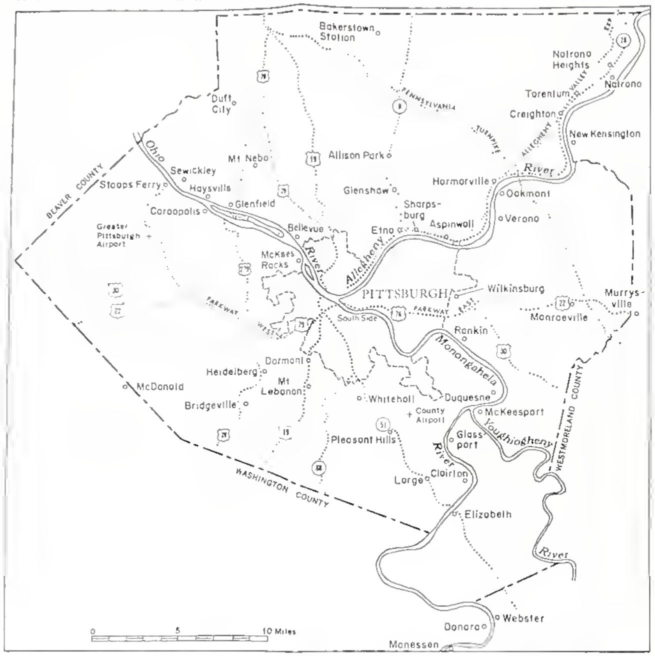


Figure A Cities, towns, and main roads of Allegheny County. Names shown are those referred to in text

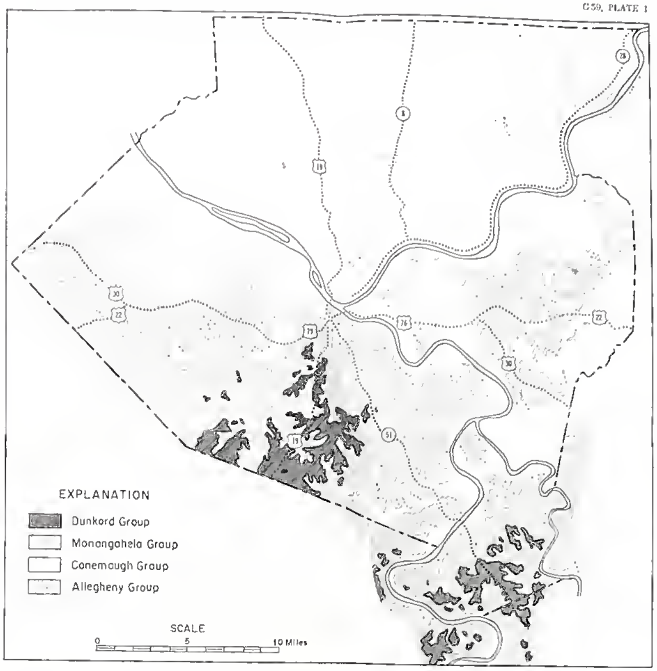


Figure B. Geologic map of Allegheny County. (Adapted from Geologic Map of Pennsylvania, 1960).

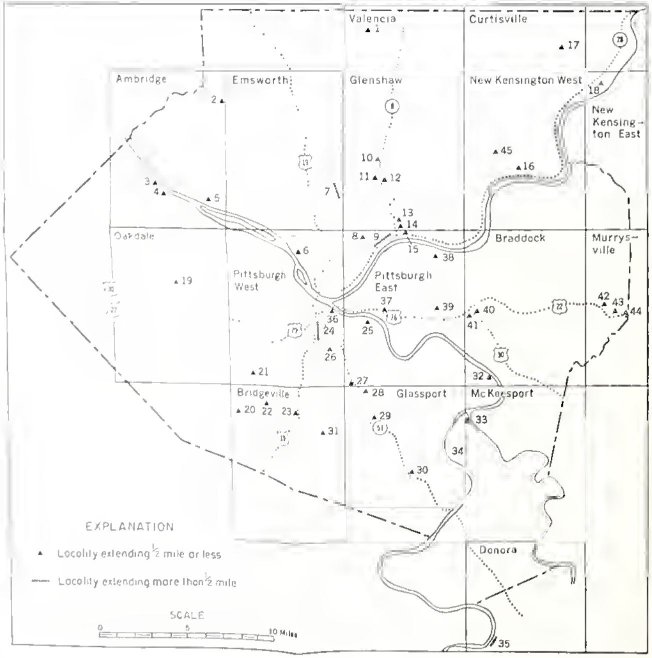


Figure D Locality map of Allegheny County. Numbers refer to localities discussed in text and in Appendix 1. Grid pattern shows the 7½ minute topographic maps in which the localities are situated.

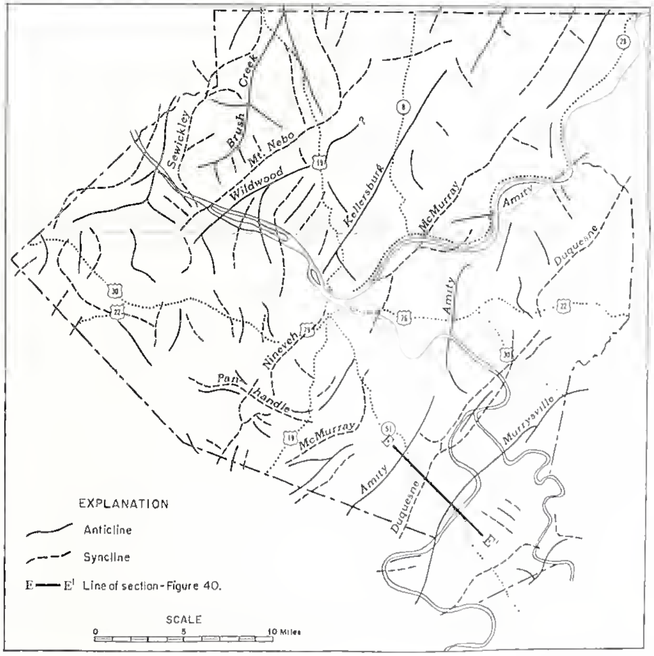


Figure C. Structural axes of Allegheny County. (Adapted from reports preceded by asterisks in Appendix 3).

Plate 1. Reference maps of Allegheny County.

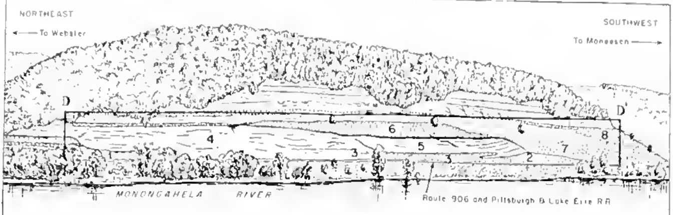


Figure A Road cut between Webster and Monessen. Outlined portion shows part of hill discussed in text and interpreted in Figures B, C, and D. This illustration is drawn from a photograph which, because of foreshortening, distorts horizontal distance.

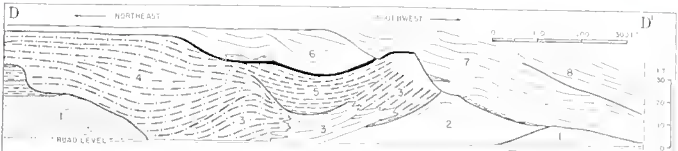
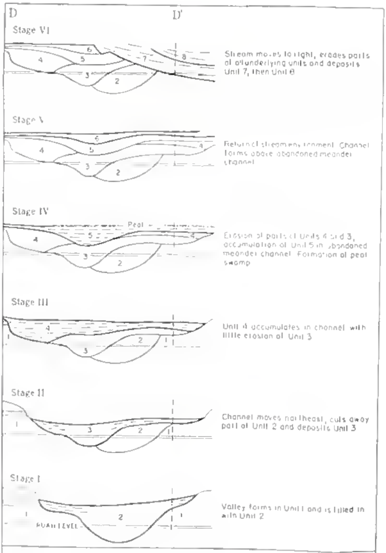


Figure B Sketch showing stream channel changes with time. Numbers indicate sequence of events from Unit 1, the oldest to Unit 8, the youngest. Lines denote relative frequency and dip of layering.



Stage VI

Stream moves to right, erodes parts of all underlying units and deposits Unit 7, then Unit 8

Stage V

Return of stream environment. Channel forms above abandoned meander channel

Stage IV

Erosion of parts of Units 4 and 3, accumulation of Unit 5 in abandoned meander channel. Formation of peat swamp

Stage III

Unit 4 accumulates in channel with little erosion of Unit 3

Stage II

Channel moves northeast, cuts away part of Unit 2 and deposits Unit 3

Stage I

Valley forms in Unit 1 and is filled in with Unit 2

Figure C Stages I to VI show development of Units 1 through 8 of Figure B

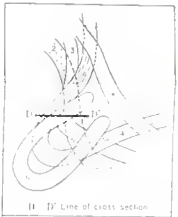


Figure D Map view of stream channel migration from time when Unit 2 was deposited until Unit 5 was deposited.

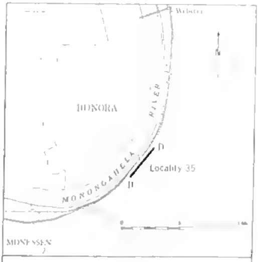


Figure E Location of Locality 35

Plate 2. Ancient stream erosion and deposition.

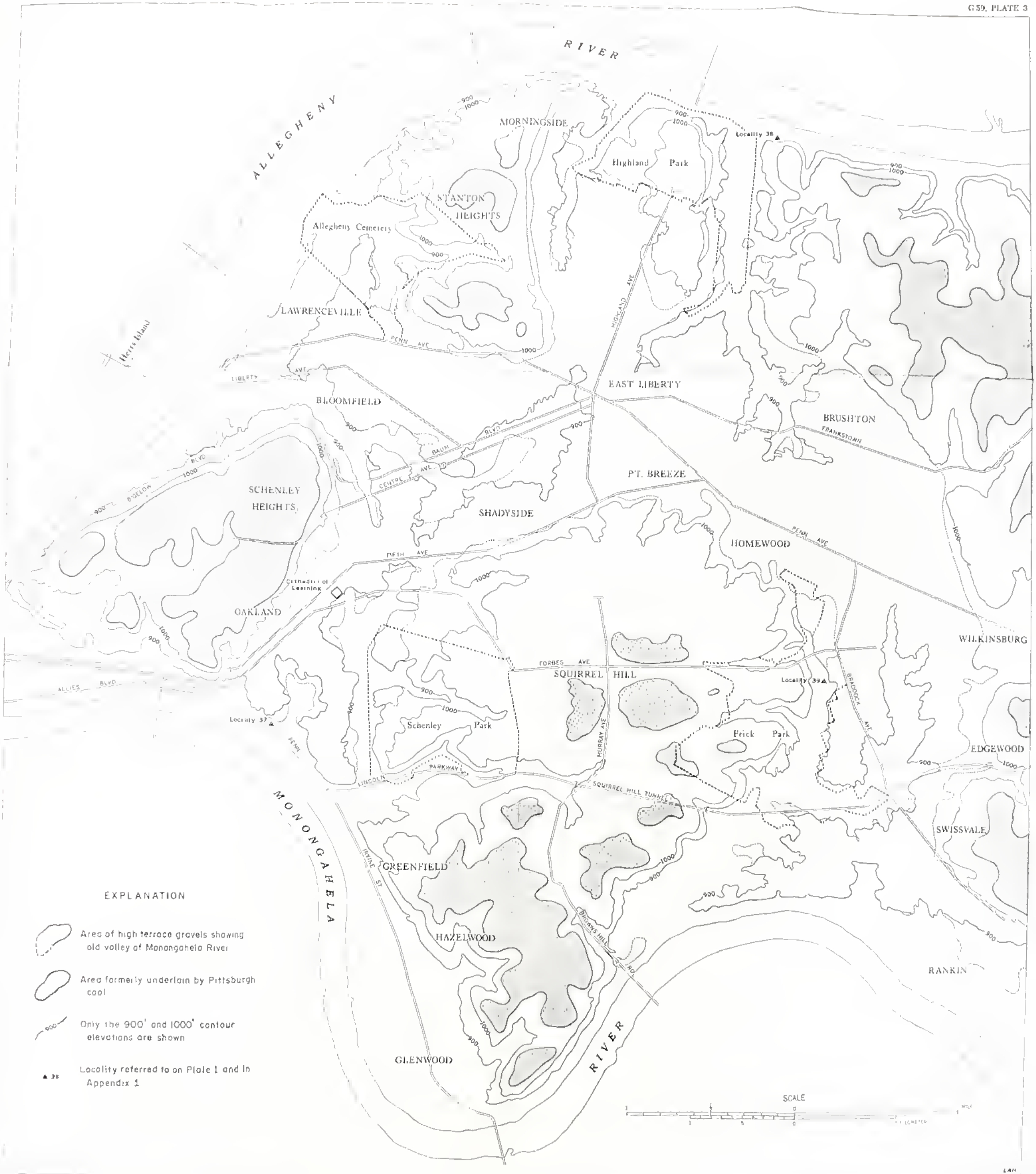


Plate 3. Detailed map of Pittsburgh showing old Monongahela channel and areas underlain by Pittsburgh coal.